New trends in stored-grain infestation detection inside storage bins for permanent infestation risk monitoring

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Abstract

Accurate and reliable detection and monitoring of insects in grain bulks is an essential part of commercial trading or research into pest management systems. Current methods of monitoring grain quality during storage have limitations, several of them sufficiently serious to prevent long-term risk assessment, a fundamental requirement of proper pest management.

New approaches in pest detection will help to change this situation. Mechanical collection and automated sieving of samples should be available in the near future to assess insect infestation in moving grain.

Integrated pest management strategies have been much improved by installation of in-bin acoustic sensors which automatically alert to the need for insect control. These systems can reduce the chances of an infestation going undetected at a lower cost than permanent chemical control.

The information provided from such monitoring tools could be linked to an expert-system that would play an active role both for risk assessment and decision-making during grain storage.

Introduction

Stored grain is susceptible to attack and damage by insects and much effort has to be expended on pest control and prevention. Monitoring of insects in stored grain can be the most costly part of grain storage management. A wide range of approaches to pest management has been attempted (Flinn and Hagstrum 1991; Subramanyam et al. 1991; Wilkin et al. 1991; White 1992) but all rely on a reliable estimate of insect numbers, which can be doubtful or impossible at very low density levels (i.e. less than 1 insect/kg of grain). Nevertheless, estimating insect numbers is also an essential part of judging the need for control measures and, therefore, a means of optimising the economics of pest control. The ability to estimate populations becomes even more important when more sophisticated pest management systems are attempted.

Methods Already Used for Insect Detection in Samples of Grain

Despite the clear need for accurate determination of insect populations in grain, the method most widely used by commerce, the assessment on samples withdrawn from the grain mass, is crude, labour intensive and insensitive. Some limitations of sampling have been revealed in pilot scale trials (Wilkin and Fleurat-Lessard 1991) through experiments in static grain bulks.

The collection and removal of samples was used for insect detection in grain bulks. Dead adult insects were added to the grain during bin loading operations at three rates: 0.2 insects/kg, 1 insect/kg and 5 insects/kg for each species. The results showed that, despite the collection of a larger number of samples than recommended in sampling standard, and of large quantities of grain, detection was only reliable at the highest population density. This work provides a clear illustration of the restricted value of collection and examination of samples to detect and estimate insects in grain even if they are dead and motionless.

The collection of a larger number of samples or greater quantities of grain per unit under examination is not usually done in grain transactions even if some tentatives are under experimental extension. When insects are alive, we have demonstrated the poor value of such means of assessment of insect density in the case of aggregative patterns of dispersion or of migration inside the grain bulk during the storage period (Fleurat-Lessard and Poisson 1982).

On the other hand, mechanical sampling allows larger quantities of grain to be obtained, with better representativeness of the samples when good sampling rules are followed. Usually, such machines work by sucking a sample of grain from the lorry, passing grain and air through a cyclone and delivering the grain to the laboratory. Work by Hurburgh et al. (1985) indicate that vacuum sampling of grains and fluid-lift conveying of samples could introduce several biases to the results of insect contamination rates (for example over-estimates of lighter dead insects, and the lethal effects of mechanical impacts during conveying). More complicated devices (i.e. cross-flow samplers) have been used for quality assessment of grain during loading of boats in different countries (Friedrich 1981; Gy 1982, 1983). Nevertheless, this method is labour intensive and these systems have been progressively abandoned. The intrinsic value of mechanical samplers in pest detection is a much debated question. Often, the plethora of samples represent a limitation for the analysis operations which follow sampling. However, automatic seeving devices for impurities grading or insect recovery in large samples (10 kg) are available (for example 'insectomat' in U.K.) and could be used for checking insect presence and numbers at a density as low as 1 insect per 5 kg of grain.

Among the promising insect-detection techniques under investigation is the detection and measurement of insect by-products, such as uric acid or CO_2 release rate in a sample of grain, or directly in a storage bin, and the use of various radiation-based methods. The latter include X-rays (ISO 1987), reflected or transmitted near infrared (Pinniger et al. 1986), or nuclear magnetic resonance (Chambers et al. 1984). All these methods are designed to work with samples of grain, often of a very limited size. The difficulties surrounding the use of samples have been detailed earlier and the same limitations will apply to any method based on samples. Even if they are

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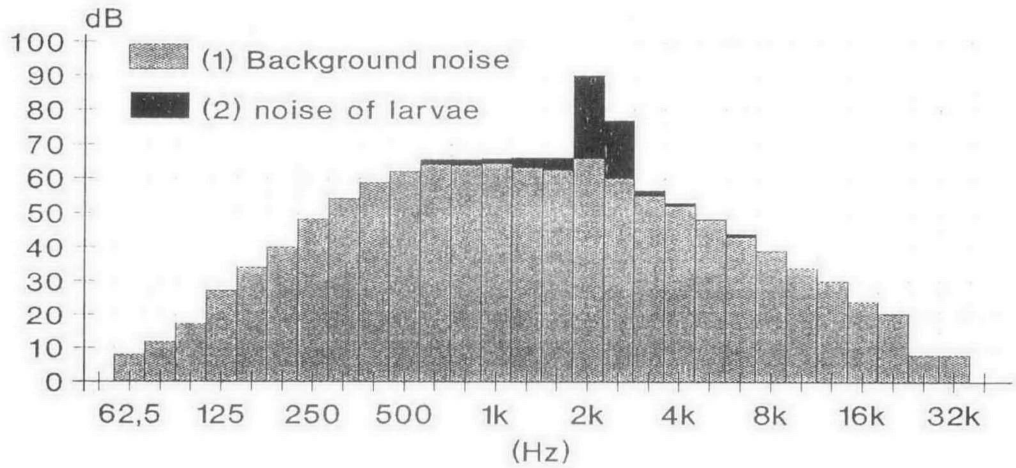

Fig. 1. Noise spectra in uninfested grain (1) and after addition of infested kernels with *Sitophilus granarius* larvae (2). (Without filter for extreme frequencies.) (With frequency filtering system.)

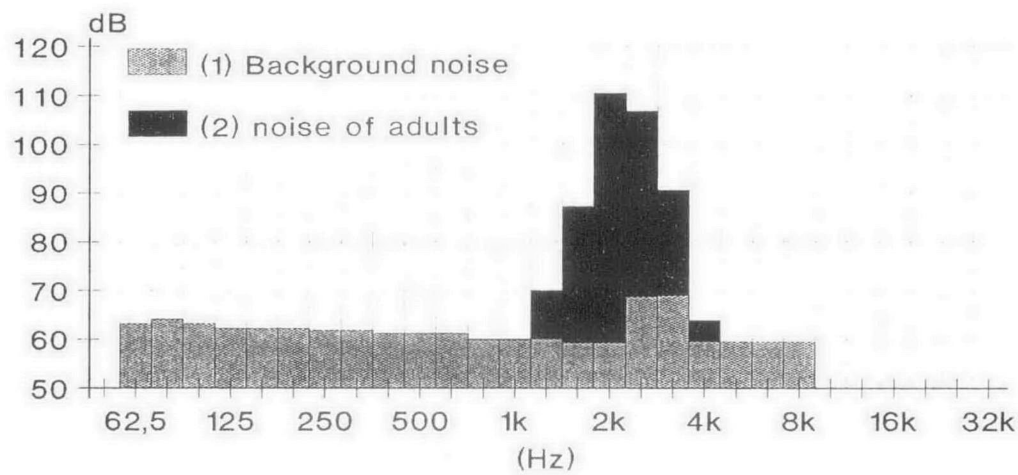

Fig. 2. Noise spectra with INRA acoustic probe in infested grain (1) and with *Sitophilus granarius* adult (2). (With frequency filtering system.)

very precise, the accuracy of the detection is depends on the reliability of the sample.

Results Obtained with Traps and Acoustic Probes

The solution to permanent monitoring of insect risks is 'in-bin detection': if insects can be monitored *in situ* it is possible that some of the limitations associated with sampling can be overcome. Trapping and acoustic detection have obvious potential for use in this way. Pitfall traps or perforated probe traps sunk into the surface or at a small depth in multi-thousand tonne bulks of grain are extensively used in spite of the absence of a scientific principals base. Results published by Loschiavo (1975), Burkholder (1983), E.J. Wright (pers. comm. 1990), Cogan and Wakefield (1987) and Wilkin (1991), confirmed that either pitfall or probe traps, or a combination of the two, were much more effective in detecting insects in static bulks of grain than conventional sampling methods. Research on trapping seems to have concentrated on enhancing the effectiveness of an already effective method by developing improved traps (Cogan et al. 1991) and by adding pheromone or food attractants to existing traps (Chambers 1987; Burkholder and Ma 1985). This work has undoubtedly been successful but fails to address the problem of interpretation of trapping results in terms of estimating insect population densities. But it is the first step in the early warning of insect presence which does not need any sophisticated material or training.

Acoustic detection relies on the sounds produced by insects as they move and feed within a grain bulk (Fleurat-Lessard and Andrieu 1986; Hagstrum et al. 1988; Andrieu and Fleurat-Lessard 1990; Flinn and Hagstrum 1991). These sounds are readily detected with relatively simple equipment but separating insect and background noise can be difficult and identification of the specific sound spectrum is extremely hard inside a grain bulk (Figs 1 and 2). Nevertheless, acoustical sensors can provide, without disturbing the grain bulk when taking a sample, density estimates that are in good agreement with estimates obtained through exhaustive systematic sampling in all locations of a grain bin (Figs 3 and 4). In addition, acoustic detection reveals the hidden infestation by the larvae of weevils and borers, which is a substantial advantage for early warning. Most of the recent development in acoustic detection of insects has concentrated on methods of analysing the sound spectrum of insect noises and developing computer-based analysis programs that will identify the insect species through their sound spectrum. This approach has a great potential for incorporation in an automated insect monitoring system in situ, directly installed inside grain bins (Fig. 5).

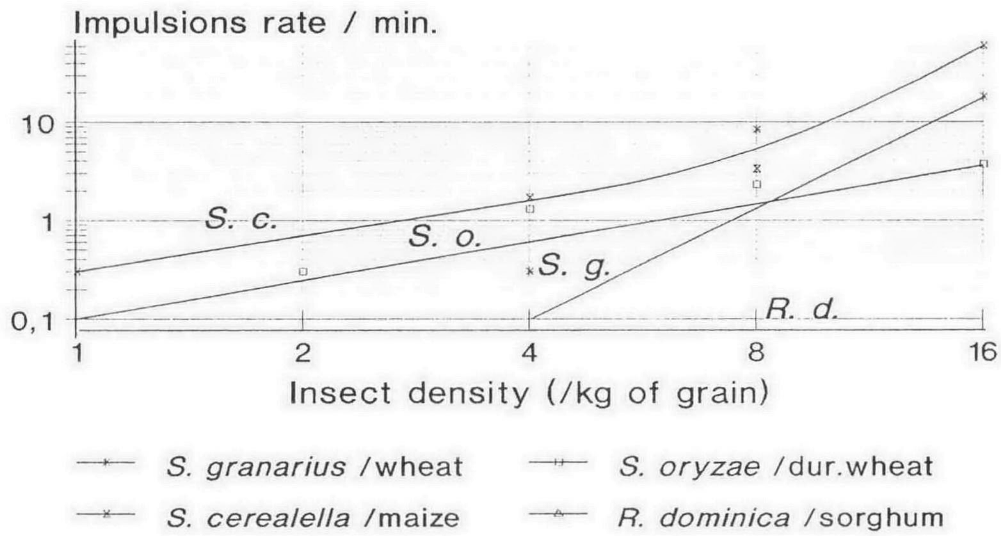

Fig. 3. Significant noise impulsions resulting from feeding activity of insect larvae in different cereal grain. (1 kg grain samples, temperature 20°C).

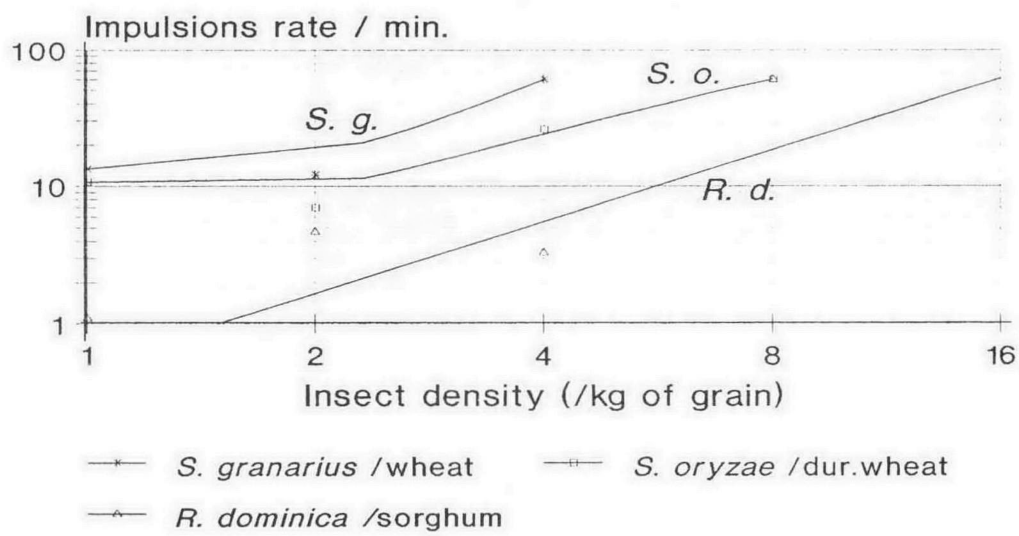

Fig. 4. Significant noise impulsions resulting from feeding activity of moving adults in different cereal grain.

The Importance of New Insect Detection Devices

Validation of early-detection devices is currently in the pre-development phase in Europe. Either probe traps or pitfall traps and acoustic probes are used in large grain storage facilities to test them in full-scale conditions and for long-term storage of grain.

For instance, an acoustic probe and recording system was used last year in France inside a large bin (650 m^3) filled with 500 t of wheat (Fig. 6). The system gave permanent information about insect activity during all the storage period. These records were of primary importance because storage was driven with a cooling aeration technique (Lasseran and Fleurat-Lessard 1991). With insect activity deep inside the grain bulk, acoustic detection will depend on temperature (Fig. 7).

It was demonstrated in France (Fleurat-Lessard and Andrieu 1986) and later in USA (Hagstrum et al. 1988, 1990) that there is a good correlation between insect noise and population density of the granary weevil. Much more reliable than pittfall or probe traps, the acoustic detection in situ, with acoustic probes installed inside bins, allows forecasting of dangerous density levels of primary noxious insect species about three or four months before reaching the critical threshold (Andrieu and Fleurat-Lessard 1984, unpublished data).

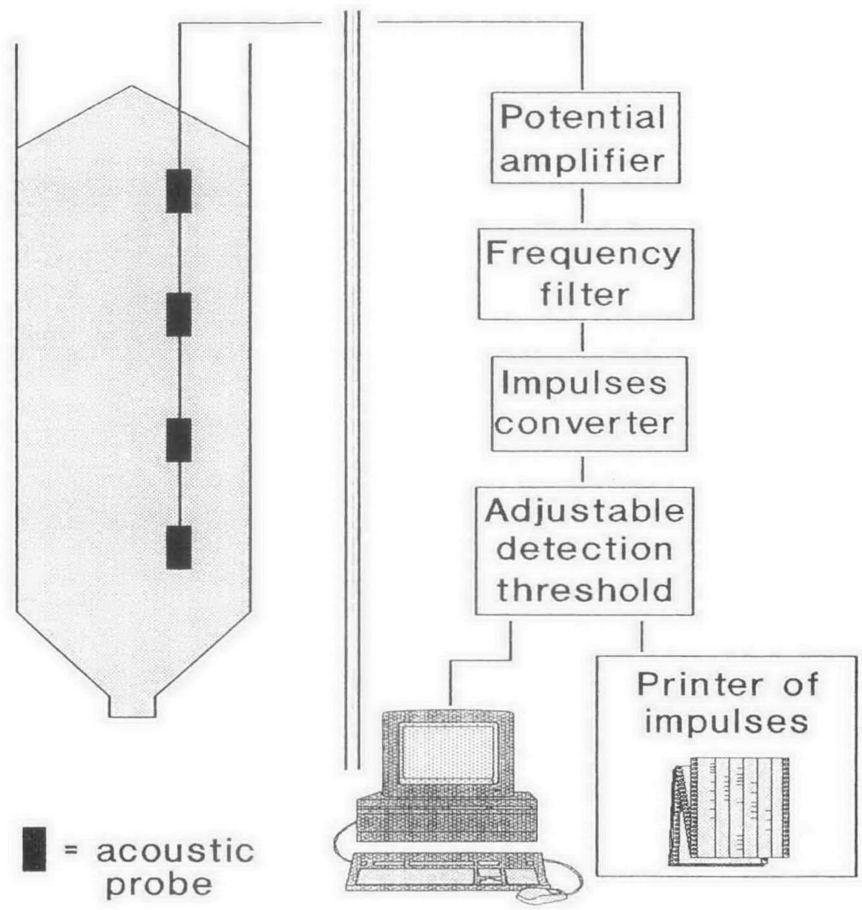

Fig 5. Detection of insects inside bins of grain with acoustical probes and a signal treatment system.

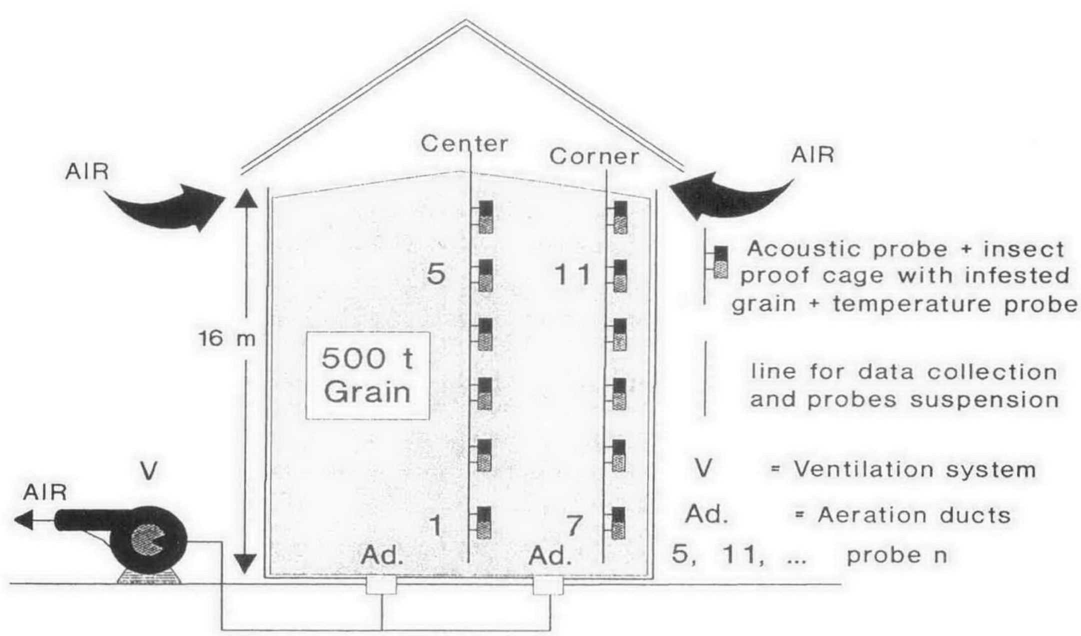

Fig. 6. Experimental bin for full-scale experimentation on insect activity during cooling of grain, recorded by acoustic probes.

With acoustical assessment of population density, insect population dynamics is accurately predictable, using only physical conditions criteria, provided that the main insect pest species are accurately characterised for biotic potential and population dynamics in different biotic situations such as fluctuations of intrinsic rate of increase on different cereal species or varieties, and temperature threshold for development (Birch 1953; Hardman 1978; Hagstrum and Throne 1989).

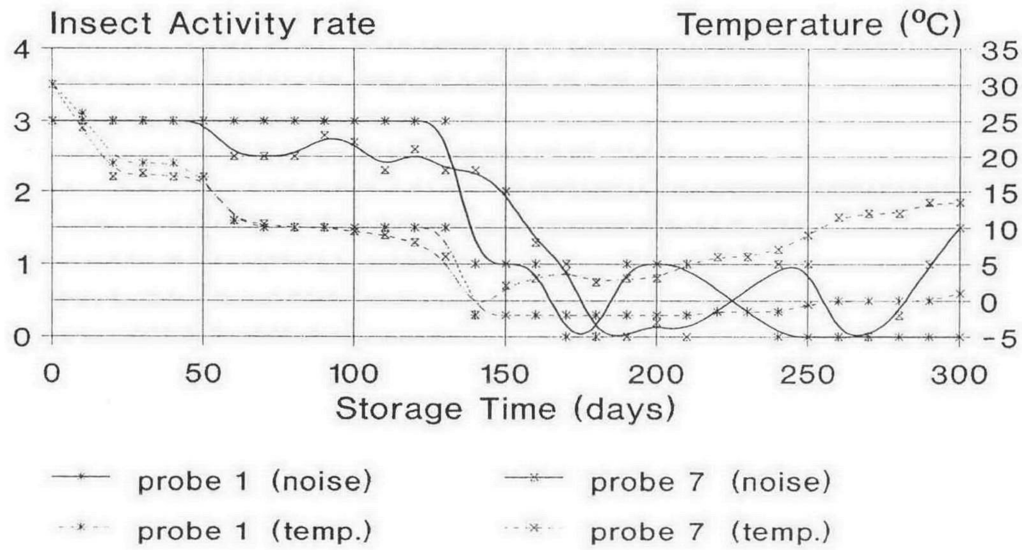

Fig. 7. Relation between insect activity recorded by acoustic probes and temperature in the grain bulk.

Further mathematical modelling for insect demography is not a constraint provided that the main physico-chemical parameters inside the grain bulk are known.

The research approach today tends to combine simulations obtained in several submodels (temperature and moisture migration related to climatic changes, ventilation or meteorological database; residual level of pesticide residues using pattern of insecticide degradation with time, for instance). Only a very small part of this modelling is useful for integration into management strategies for insect infestation in static grain bulks. The ability to forecast population trends for providing as soon as possible prophylactic and remedial advice is only possible if the lowest level of density or activity of insect is detectable in the grain bulk. Most modelling tentatives are based on population density levels much higher than the tolerance threshold, or only use fictive density rates for simulation. All the expert systems under study for grain pest management during storage need an early warning system such as acoustic probes (Flinn and Muir 1992).

Conclusion

Accurate and reliable detection of insects in grain is an essential part of commercial trading or research into pest management systems, especially through the actual development of expert systems designed for the monitoring of grain quality during all the conservation period (Ndiaye 1994). Current methods have serious limitations, several of which are sufficiently serious to prevent long-term risk assessment, a fundamental requirement of proper pest management.

New approaches to pest detection will help to change this. Work on mechanical collection and automated sieving of samples is under way, and commercial equipment to assess insect infestation on samples collected in moving grain should be available in the near future. Integrated pest management strategies have a great deal to commend them in the field of static bulk grain storage, particularly when long-term storage is being attempted. Permanently installed acoustic sensors, which automatically indicate the need for insect control, can improve pest management by reducing the chances of an infestation going undetected. Ultimately, the results from such monitoring could be linked to an expert system that would play an active role both for risk assessment and decision-making during grain storage.

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