Insect pest monitoring in museums - old and new strategies

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DOI 10.5073/jka.2018.463.056

Abstract

Integrated Pest Management (IPM) is an important part of preventive conservation of museum objects made of wood, textiles, starch, paper, keratin and other organic materials. Long term monitoring data help us to discover new infestations and locate them in the building. Results from over 20 institutions (museums, storages, historic libraries and historic palaces) are presented and discussed how the monitoring can be improved, where active infestations were found, what treatment was done as a response and what new methods are used. What pests are the most abundant, which species are new for the indoor museum environment and when do we actually have active infestation and damage of museum objects? Monitoring and IPM in museums is also compared with the food storage industry. IPM is applied in many museum today, mainly to reduce the application of pesticides, for a long-term protection of the objects and collections and early detection of infestations. In this presentation, long term monitoring data with sticky blunder and pheromone traps for webbing clothes moth Tineola bisselliella is described. The analysis of the data show that in all museums and storages buildings with a monitoring in place different insect pest species are present, but only in few collections damage to museum objects was found. New pests like the grey silverfish Ctenolepisma longicaudata and Ctenolepisma calva - another species of Lepismatidae, are now found in many museums in Vienna, Austria. The odd beetle Thylodrias contractus was found recently in Austria, surprisingly in four different locations.

Remote monitoring of stored grain insect pests

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DOI 10.5073/jka.2018.463.057

Abstract

A number of remote sensing methods were developed and tested in commercial grain warehouses; probe pitfall traps attached to vacuum lines, surface pit fall traps equipped with video cameras and white boards on grain surface monitored with video cameras. These methods were compared with detecting insects using grain samples. Warehouse trials by trapped methods were carried out in bins with 8520 t of wheat from 23 May until 8 August 2016.Grain temperatures were from 22.7 to 31.6℃. Psocids, *Liposcelis bostrychophila* Badonnel, were detected by grain samples, but there were higher number of pscoids trapped with the probe pitfall traps and pitfall traps than found in grain samples. *Plodia interpunctella* (Hübener), *Sitophlius zeamais* Motchulsky and *Cryptolestes ferrugineus* (Stephens) were detected by probe pitfall trap, but not in the grain samples. *S. zeamais* was detected by the pit fall traps. Using the remote controlled video camera in the warehouse head space, we were able to distinguish and count *S. zeamais*, *C. ferrugineus* and psocids on white boards. The video from pitfall traps can be sent to mobile phones. With all these methods, data can be collected remotely, and could be analyzed by imagine analysis allowing for rapid real time monitoring of insect pests.

Keywords: stored grain insect; monitoring; remote; feasibility

1. Introduction

Efficient sampling is a decisive factor for the timely and safe undertaking of measures in the management of stored products and foods (Buchelos and Athanassiou, 1999). Timely monitoring is necessary for pest management of stored grain, especially for wheat and paddy rice which can be stored for three to five years in China. The need for as many samples as possible, as frequently as possible, is a technical problem of conventional sampling methods (Subramanyam and Hagstrum, 1995). Sampling and sieving grain is a current method in stored insect monitoring as recommended in Chinese grain storage regulation. The grade of insect infestation of stored grain is decided by sampling, although this technique is effective primarily for detection of adults and some larvae.

Manual sampling of insects in stored grain is a laborious and time-consuming process (Flinn et al, 2009). Over the past few decades, many researchers have developed traps for use in store facilities as an alternative sampling method (Buchelos and Athanassiou, 1999). Probe traps, when compared to other trap types, have given satisfactory results in the trapping of many important Coleoptera and other stored product species; at the same time, they are easy to use and reliable even without the use of an attractant (Lippert and Hagstrum, 1987; Subramanyam et al., 1993; Fargo et al., 1994； Buchelos and Athanassiou, 1999). Pitfall traps were also developed for insects that are active on top, higher temperature, layer of grain bulk in summer. Automation of grain sampling and insect monitoring should help to increase the adoption of stored grain integrated pest management. A new commercial electronic grain probe trap (OPI Insector) has recently been marketed (Flinn et al, 2009). A probe pitfall traps system attached to vacuum lines had been developed ten years ago in China. The insects can be vacuumed from trap bottom through the line by remote control and then counted. Another approach is the use of a video camera in the headspace of grain warehouse which can be controlled remotely to capture insect pictures when they walk on a white board that was laid on surface of grain bulk. This method has been used in grain depots of Sino-grain. A surface pitfall trap equipped with video cameras was made and the captured pictures can be monitored by mobile phone. Here some insect monitoring results were reported for a number of remote sensing methods, including probe pitfall traps attached to vacuum lines, surface pitfall traps equipped with video cameras and white boards on grain surface monitored with video cameras. These methods were compared with sampling insects using grain samples.

2. Materials and Methods

2.1. Trial 1

The plastic probe pitfall traps, attached to vacuum lines (PPTAVL), consisted of probe with hole, on its wall were holes insects can go through, insect collecting chamber on bottom, after insect fall in, and vacuum line for sucking out the collected insects in the chamber. The vacuum line was connected with vacuum pump, insect collecting bottle, insect checking sensor, and remote controller (Fig. 1). The probe pitfall was inserted into grain mass so that the head was beneath the surface of the bulk.

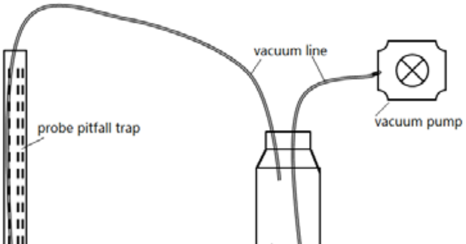

Fig. 1 Diagram of the probe pitfall trap with attached vacuum line.

The surface pit fall traps equipped with video cameras（SPTEVC） consisted of a disc contained radial channels, where insects can through, insect collecting chamber attached centrally below the disk, video camera right over the chamber, communication device with WiFi (Fig. 2). It was mostly made of plastic. Insect collecting chamber in the SPTEVC was inserted into top layer of bulk. The disk with the Insect going channels was laid on the level of bulk surface while monitoring. The insect trapped in the chamber were collected manually.

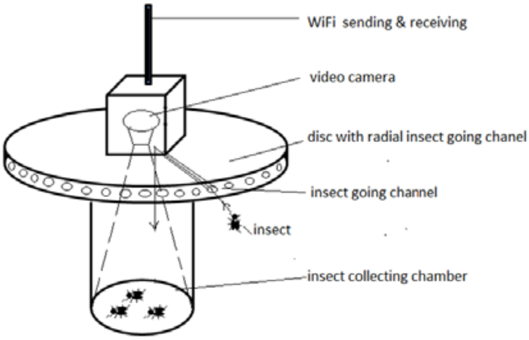

Fig. 2 Diagram of the surface pitfall trap equipped with video camera.

Sampling check was carried out using one kilogram grain samples for each monitoring time and position. The relative distance among between traps, grain sampling location, and warehouse walls, was one meter. There were five sets of traps and sampling points located in four corners and one central position in the storage which contained 8520 tons of wheat (Fig. 3). The stored wheat was loaded in June 2015 with 12.6% moisture content and 784 g/L test weight. The highest temperature average was 20.2℃ and and the lowest 0.1℃ in the winter of 2015. On the beginning of the trial, May 16th of 2016, insect density was zero per kilogram of grain by sampling method for beetle, moth and psocids.

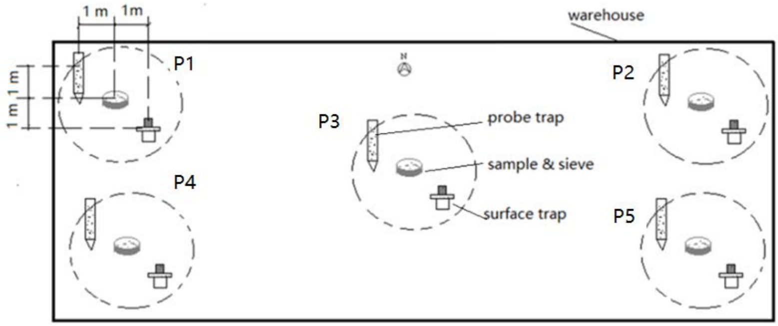

Fig. 3 Traps, sample position and five sets on grain bulk of the warehouse

2.2. Trial 2

White boards on grain surface were monitored with video cameras（WBMVC）to measure insect activity. One high definition video camera was set up in headspace of a warehouse, in which 7000 tons of wheat was stored in bulk. The video camera can scan whole surface of the bulk remotely to get clear figure of insect on grain surface, as is shown at Fig. 4. A white board with 1 cm grid pattern was laid on bulk surface. The insects that crawled on white board, even psocids, can be seen on screen of a remote control computer (Fig. 5).

Fig. 4 A picture of psocids on grain bulk surface captured by computer from high definition video camera

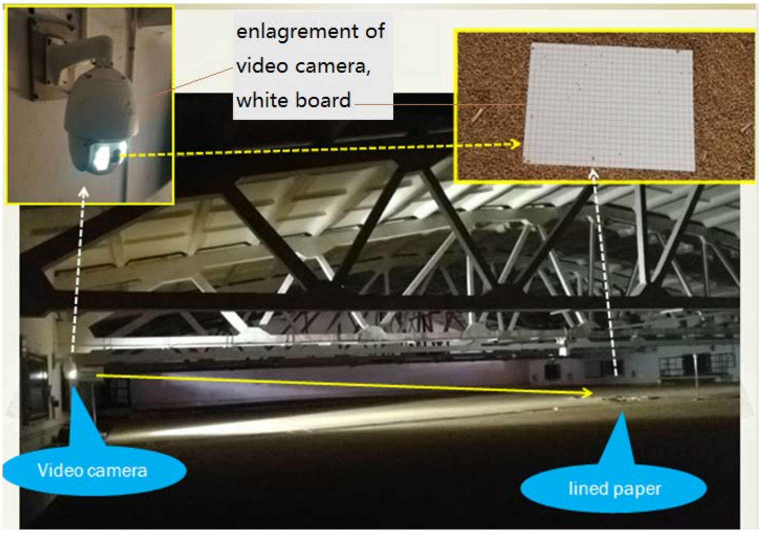

Fig. 5 The white board laid on surface and video camera in headspace of warehouse

2.3. Insect checking and handling

In trial 1, insects were monitored, and samples collected and checked, once a week. The number in traps was recorded as adults or larvae per week. The number in sample was recorded in adult per kilogram of sampled grain. All insects in traps were removed at each checking time. In trial 2, the picture was captured once a week. The dark spot in different sizes and outline shape of insects on white were checked and counted.

3. Results

3.1. The species detected by the different monitoring methods

During the monitoring time from May 16th to August 8th, *Liposcelis bostrychophila* Badonnel was trapped in PPTAVL and PTEVC and found in sieved samples. *Plodia interpunctella* (Hübener), *Sitophlius zeamais* Motchulsky and *Cryptolestes ferrugineus* (Stephens) were detected by probe pitfall trap, but not in the grain samples. *S. zeamais* was detected by the pitfall traps. The method of sample and sieve only detected the psocids even when beetles and moths were exiting in grain mass.The pitfall trap captured S. zeamais and *L. bostrychophila*, but not *P. interpunctella* and *C. ferrugineus* even though the probe pitfall trap can trap all the insects mentioned above.Due to the random distribution of insects in different monitoring locations, the probability of detection is very different in the same monitoring method for the detected species. In these methods, however, the ability to detect insect species is obvious.

3.2. Comparison of number of captured insects using different methods

The insect number monitored by same method varied among the five positions at same checking time. The numbers at different checking times also varied for insect species and monitored methods in all trials. And the number of insects sharply varied among different methods at same positions (Table 1). For example, on May 23rd, 32 adults of *L. bostrychophila* in one week was trapped in PPTAVL which was obviously more than the 5 adults captured at the same time in PTEVC. There were eight *L. bostrychophila* adults sieved from grain sample. It means that the psocids can be checked or attracted by the three methods, but that they may be detected in greater numbers in probe pitfall trap.

The number of beetles and moths captured in two trapping methods was obviously different, although few insects were trapped in the trap trials. *P. interpunctella* number was 1-3 larvae per week detected by probe pitfall trap and zero per week captured in pitfall trap. The number of *C. ferrugineus* captured was 2-5 adults per week in probe pitfall trap and zero per week in pitfall trap. For *S. zeamais* was 1-3 adults per week in the probe pitfall trap and only one per week in pitfall trap. The pitfall trap set on surface of grain mass detected fewer beetles and moths than probe pitfall trap inserted into the bulk. Sampling and sieving method detected no beetles or moths, which indeed existed in the grain mass during June 20th to August 8th.

3.3 Insects on white board under of video camera

A picture from video camera in headspace of grain warehouse of the white board was captured on computer as shown in Fig. 6. The biggest dark spot was revealed as a *S. zeamais* adult, the middle sized dark spot was a *C. ferrugineus* adult, and the smallest dark spot indicated that *L. bostrychophila* crawled on the board. The species judging was based on dark spot size, picture outline and experienced knowledge. The picture captured by computer received from video camera can provide information about insect species and dynamic number during monitoring. Insect number or population dynamic can be known by counting the dark spots in 1 cm subsample or on whole white board at any time.

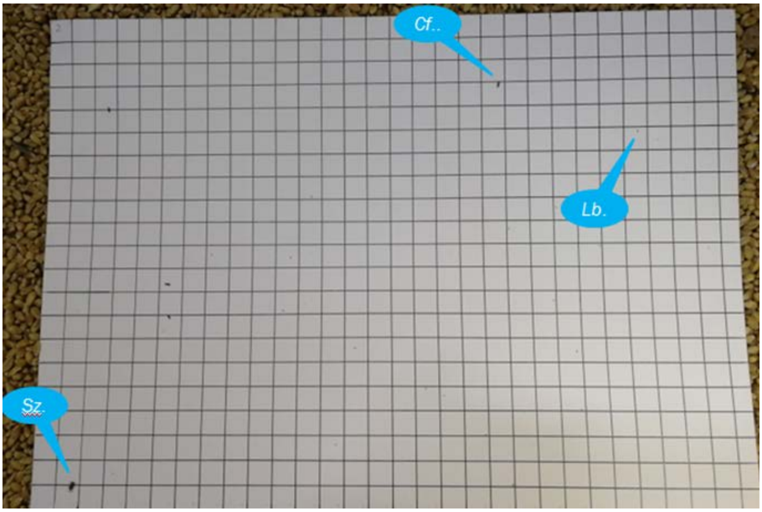

Fig. 6 Identification of insects on white board made from a image captured from a video camera (Sz for S. zeamais, Cf for *C. ferrugineus* and Lb for *L. bostrychophila*.

Tab. 1 Insect number captured by traps or recovered in grain sample.

Date /Month· Day	Temperature outside of warehouse /°C	Temperature in headspace /°C	Temperature of bulk /°C	*L. bostrychophila* in PPTAVL (adult/week)	*P. interpunctella* in PPTAVL (adult/week)	*S. zeamais* in PPTAVL (adult/week)	*C. ferrugineus* in PPTAVL (adult/week)	*L. bostrychophila* in PTEVC (adult/week)	*L. bostrychophila* sieved from grain (adult/kg grain)
5.16	20.0	25.0	20.8						2
5.23	26.0	28.0	22.7	32.0				5	8
5.30	24.0	28.0	21.8	80.0				10	30
6.06	22.0	27.0	23.2	100.0				15	30
6.13	26.0	31.0	23.6	180.0				15	25
6.20	27.0	35.0	25.5	190.0	1.0			10	30
6.27	24.0	32.0	28.8	130.0	1.0			5	25
7.04	24.0	34.0	28.9	85.0				3	23
7.11	28.0	33.0	29.4	67.0	3.0			5	27
7.18	25.0	32.0	28.9	76.0	2.0	1.0	2	4	33
7.25	29.0	36.0	30.3	65.0	2.0	3.0	2	6	40
8.01	29.0	38.0	32.5	5.0	2.0	3.0	5	1	2
8.08	26.0	35.0	31.6	15.0	1.0	3.0	2	8	10

4. Discussion and conclusions

Remote insect monitoring is being realized by insect sensors and remote information transfer which should be more convenient than manual methods of insect detection in grain storage. Accurate monitoring is needed and spatial analysis techniques are increasingly being used in entomological investigations (Liebhold et al., 1993; Trematerra and Sciarreta, 2004). These techniques apply specialized software to trap captures, interpolating the data from the sampled locations to generate data for a non-sampled location. All these data are subsequently represented in contour maps, from which a wide range of information can be obtained, notably the distribution of different pest species in space and time (Schotzko and O'Keeffe, 1989; Arbogast et al., 2000; Campbell et al., 2006; Trematerra and Sciarreta, 2004), their movements through facilities (Campbell and Hagstrum, 2002; Arbogast et al., 2002; Athanassiou et al., 2005). It is important to know the relationships for different species of insect between trapping and sampling & sieving under specific cases such as grain storage types, warehouse conditions, capacities of the bulk, temperature of grain mass and warehouse, quality of stored grain, status of insect infestation.

With the results in this research psocids can be found by traps and sampling. But there were higher number of psocids trapped with the probe pitfall traps and pit fall traps than found in grain samples during whole monitoring process. *P. interpunctella*, *S. zeamais* and *C. ferrugineus* were detected by probe pitfall trap, but not in the grain samples. *S. zeamais* was also detected by the pit fall traps. All detected information of insects was able to be transfered and controlled remotely. Using the remote controlled video camera in the warehouse head space in other trial, we were able to distinguish and count *S. zeamais*, *C. ferrugineus* and pscoids on white boards. All information can help us to improve pest management by indicating if it needed to kill the insect or not. It can also increase the effectiveness of treatments (Brenner et al., 1998; Blom et al., 2002; Campbell and Hagstrum, 2002) and reducing prospects for the development of resistance (Belda et al., 2011). Consequently treatments costs of insect monitoring may be reduced due to reducing on manual work.

Acknowledgement

We thank Paul Fields of Agriculture and Agri-Food Canada for reviewing an earlier version of the manuscript.

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Can the DI-SPME gas chromatography mass spectrometer be a tool for identification of stored grain insects - fatty acids and sterols profiling

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DOI 10.5073/jka.2018.463.058

Abstract

Identifying insect pests is essential for management, but these insects can only be reliably identified by a limited number of highly skilled taxonomists. Expert morphological determination can require dissection and slide mounting of specimens in order to examine distinguishing diagnostic features. Suspected insect pest specimens found in grain products usually consist of only the larvae or larval skins which are very difficult to identify to species, and sometimes impossible to diagnose morphologically. Adult specimens are usually scarce and more often damaged. Misidentification of species could lead to misled pest management practice.

Fatty acids (FAs) have long been recognised as biochemical markers for organism classification. The direct immersion solid phase microextraction gas chromatography-mass spectrometry (DI-SPME-GCMS) technology has been developed and validated for selectivity and accuracy by isolating fatty acids from natural fatty acid methyl esters. Seven different species of stored grain insect pests were analysed by using DI-SPME-GCMS method profiled fatty acids and sterols from insect extractions. Palmitic acid (C16:0), Stearic acid (C18:0) and Oleic acid (C18:1) were absorbed. The ratio of FAMEs/FAs (ME) were calculated and validated as a new biomarker for insect classification. Mid-