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An Urban Eradication of Khapra Beetle in Western Australia

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Abstract: The khapra beetle (*Trogoderma granarium*) is one of the most serious pests of stored grain and is a regulated quarantine pest in most countries. In April 2007 khapra beetle larvae and adults were found in a suburban residence and personal effects of a family that had migrated to Perth, Western Australia two weeks earlier. Immediate and uncompromising action was taken through industry and government collaboration to quarantine the home and fumigate with methyl bromide at the internationally agreed khapra beetle rate of $80g/m^3$. Technical issues are described whereby the two-storey home was shrink-wrapped to ensure that gas concentrations were maintained and monitored for 48 hours. A number of social challenges were encountered dealing with nearby families during the treatment and removing the malodour from the property afterwards. A two-year trapping program was undertaken to validate the complete eradication of the pest.

Key words: khapra beetle, *Trogoderma granarium*, fumigation, eradication, biosecurity

Introduction

The khapra beetle, *Trogoderma granarium* Everts (Coleoptera: Dermestidae) is a stored product pest of great significance and is nominated as one of the 100 worst invasive species worldwide[1]. It infests grain and cereal products, particularly wheat, barley, oats, rye, maize, rice, flour, malt, and noodles, although it will feed on almost any dried plant or animal matter[2].

Khapra beetle's importance however, lies not only in its capacity to cause serious damage to stored commodities, but also the impact it has on trade for countries that have established infestations. Quarantine regulation can also be imposed if the pest is detected in export produce, containers or packaging from any country. In 2007 – 2008, news media reported on numerous khapra beetle related quarantine incidents involving rice, soybeans and cotton moving between Russia, Uzbekistan, Pakistan, Mexico, U. S. A. and China[3].

Identification of khapra beetle is difficult[4] and Australia was inadvertently recorded as a "khapra beetle country" in the 1950's due to a misidentification of a non-pest native beetle[5]. It took many years of international lobbying to be removed from this list and even today there are occasional databases that report the error[6]. To protect its reputation as an exporter of clean grain, Australia has maintained a rigorous protocol of pre-loading inspection of export ships to ensure there is no residual infestation especially given the khapra beetle can exist without food in a fumigation-tolerant state of facultative diapause for many years[7].

Most years khapra beetle are intercepted at ports by Australian Quarantine Inspection Service (AQIS) pre-shipment inspectors in vessel holds and especially ship's stores requiring treatment before loading. The khapra beetle has never been found in Australia so it was with the greatest concern that a post-border detection of khapra beetle was recorded in April 2007 infesting personal effects in a suburban household in Perth, Western Australia.

This paper reports as a case study, the immediate and uncompromising action taken by Australian government and grain industry to fumigate the incursion and the ongoing trapping to reinforce complete eradication.

Methods

Diagnosis and Response

The khapra beetle incursion was initially reported by a couple who had emigrated to Australia from the U. K. two weeks earlier. They were disturbed by the presence of beetles, lar-

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vae and cast skins throughout their belongings which had taken 6 weeks to arrive by ship. They sought help from a commercial pest controller who recognized the suspicious beetles from various literature and reported it to the Department of Agriculture and Food, Western Australia (DAFWA) who sent an inspector to collect specimens. Adult and immature specimens from a breeding population were identified by the DAFWA taxonomist based on examination of larval and adult stages of the insect. The insect identification was later confirmed by CSIRO Entomology, Canberra.

An assessment by the Australian Bureau of Agricultural and Resource Economics (ABARE) of the potential economic impact of khapra beetle in Western Australia[8], based on costs associated with export market losses ranged from $ 46 million to $ 117 million/year, while the present value of costs over a 30 year period ranged from $ 200 million to $ 1.6 billion. The incident was considered by the Australian Consultative Committee on Emergency Plant Pests to be a detection of an Emergency Plant Pest and consequently the processes as defined under the Emergency Plant Pest Response Deed and PLANTPLAN would be followed requiring immediate eradication.

The spread potential from the suburban site was considered low given that the infested house is 22 km from the nearest grain handling facility and about 40 km from the grain export terminal. The khapra beetle does not fly and its wider dispersal is usually dependant on human activity so the decision was made to fumigate the entire house and contents with methyl bromide under plastic sheeting at the internationally recognised "khapra beetle rate".

This is also the current recommended rate to be used by AQIS for khapra beetle fumigation (T9056) of 80g/m^3 methyl bromide for 48 hours at 21 ℃ at normal atmospheric pressure with an end point concentration at 48 hours of 20g/m^3. The fumigation must undergo monitoring at 24 hours to ensure a minimum concentration of 24g/m^3 and an additional 8g/m^3 for each 5 ℃ the temperature is expected to fall below 21 ℃ to a minimum of 10 ℃. It is the minimum temperature during the course of the fumigation that can be used for the calculation of the dose. AQIS does not accept dosage compensation for temperatures above 21 ℃ or below 10 ℃.

Western Australian bulk grain handler Co-operative Bulk Handling (CBH Group, http://www.cbh.com.au) were the obvious choice to perform the fumigation given their expertise in large sheeted fumigations. CBH Group have an interest in exporting clean grain and immediately agreed to do the work on a cost-recovery basis.

The residents were immediately moved to hotel accommodation with only the clothes they were wearing and their laptop PCs. To minimize the chance of the khapra beetle spreading while preparing for the fumigation, the house and car were treated internally by a commercial pest controller with Permethrin and the exterior and gardens with Bifenthrin. Cardboard removalist cartons, a known harbourage of khapra beetle, were loaded into a fumigation trailer and treated with methyl bromide on-site then buried. Additional high-risk personal items and packaging remaining in the adjoining garage were placed into sealed quarantine plastic bags, sprayed with Pestigas. The sealed quarantine bags were opened prior to the house fumigation to ensure gas penetration.

Treatment

The two-year-old two-storey townhouse was covered with plastic sheeting on May 3, 2007 by contractors Under-Raps (http://www.underraps.com.au) who specialise in encapsulation and shrink wrapping, using industrial grade 200

Fig. 1 The two-story townhouse before and after shrink-wrapping

low density polyethylene plastics. Shrink wrap plastics have several advantages over older techniques using tarpaulins or canvasses. They fit more tightly around the structure, reducing wear and tear in windy conditions and the plastics can be welded together onsite using hand held heat guns, and shrink tapes.

Three gas introduction points and four electric fans were placed throughout the house however, given the superior state of sealing afforded by the shrink-wrap process, the methyl bromide was able to be introduced through only one point in the upstairs roof space. The other introduction points were not required because the gas dispersed throughout the house and adjoining garage rapidly and evenly.

Six gas monitoring points and one temperature probe were installed in areas that were considered to be the most demanding. Two hours after introduction of 100 kg of methyl bromide five of the monitoring points showed the maximum concentration readable by Drager tubes of 80g/m^3 and one point at 68g/m^3. The average recorded could have been well over 80g/m^3 if the gas monitoring equipment was able to read higher. After 24 hours the average concentration was 39. 8g/m^3 and at 48 hours 30. 8g/m^3. The average temperature over 48 hours on the concrete lower floor was 20. 7 ℃. Ambient wind speeds were quite low averaging 16. 7 km/h during the fumigation

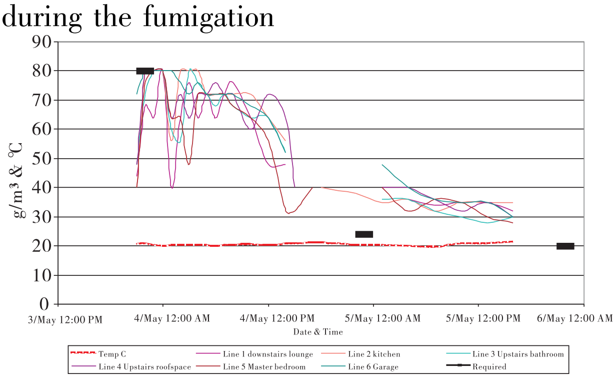

Fig. 2 Methyl bromide gas concentrations and temperature throughout the treatment period

Monitoring data shows a very effective fumigation with the khapra beetle rate exceeded. Occasional dips over one reading are suspected to have been caused by inadequate flushing of the long monitoring lines before taking the reading.

Aeration

Aeration began on the late evening of May 5 by gradually cutting holes in the wrapping. Ambient wind speeds continued to be low averaging 15. 4 km/h during the aeration. Within 12 hours the methyl bromide concentration in the house was down to the TLV (threshold limit value) of 5 ppm however there were pockets of higher concentrations in household items like cushions, bins, hot water bottles and unopened confectionery. As a result it was not until May 11 before the house could be cleared for occupation. This delay required the hiring of security guards to protect the open house.

Post-treatment Cleaning

Professional cleaners were engaged as soon as the house was habitable and they cleaned and deodorised all floors cupboards, blinds, windows (inside and out) and steam-cleaned the carpet. Unfortunately there was a distinct malodour throughout the house that was particularly bad in a carpeted room downstairs. This odour apparently had sulphide and butylketone components because it smelled very bad and the decaying body smell attracted many blowflies and flesh flies to the house adding to the resident's displeasure. The smell appeared to be coming from the low quality rubber carpet underlay.

The house was not considered habitable due to the malodour which Chemistry Centre (WA) were engaged to analyse and identify. CCWA tested for sulphur and phosphorus compounds with an AP2Ce flame spectrophotometer-based hand held chemical warfare agent detector. Ammonia, carbon monoxide and volatile organic compounds at a detection limit of 1 ppm were analysed with a Hapsite portable gas chromatograph operating in high sensitivity mode. Two SUMMA canisters were also used to collect air samples from inside the house for laboratory analysis at CCWA. No volatile organic compounds were detected above ambient (1 ppm (V)) using the hand held detectors however the portable gas chromatograph detected a number of compounds. In the upstairs bedroom methyl bromide, dimethyldisulphide, toluene, ethylacetate, and methyl isobutylketone were all detected while, in the lounge and kitchen, only methyl bromide, dimethyldisulphide and toluene were detected. The SUMMA canister sample collected in the lounge indicated there was > 0. 1 ppm (V) of methyl bromide, 0. 5 ppb (V) of toluene and 1. 5 ppb (V) of dimethyl disulphide (relative to toluene).

The malodour was evidently dimethyldisulphide, most likely formed from reaction with sulphur in the poorly refined carpet underlay. The decision was made to remove and dispose of the carpet, underlay by deep burial. CCWA recommended vigorous airing of the house to remove the smell and that this should be done prior to replacing the carpet because it could result in the malodour molecules dropping from the walls into the new carpet and tainting it as well.

Two 4 200 L/sec industrial fans were used to blow the smell out of the house by positioning one fan in a downstairs doorway blowing into the house and the other on an upstairs balcony blowing out. Doors and windows were adjusted to maximise the airflow through all rooms and the fans run for 12 hours. The malodour could be smelt 50 m into the street however in the house the odour, while not as bad, was still obvious.

In a further attempt to remove the smell an industrial ozone generator designed to cover a 1 000 square foot area, capable of producing 8 000mg/hr ozone was run upstairs for 12 hours. Fortunately, it almost completely removed the smell so a second unit was deployed and both were run continuously upstairs and downstairs for 24 hours. A follow up air measurement by CCWA showed the dimethyldisulphide was now down to 0.4 ppb.

However, the residents felt that the remaining smell left the house uninhabitable so all carpets and underlay were removed and buried at a toxic waste dump along with the plastic sheeting used to cover the house. All furniture was placed in the garage and a forensic cleaning company Grimescene Clean (http://www.grimescene.com.au) engaged to fog the inside of the house with alcohol-based products "GOE" Bio, "GOE" Washdown and Odor Eliminator "Cinnamon Spice". Areas treated were:

- Upstairs roof space, lifting insulation batts and delivering a fine mist of odour eliminating chemicals to entire area
- Main bedroom concrete floor pad, walk-in robe, including individually fogging numerous handbags, belts and items contained on the top shelf
- Main bathroom and toilet, including all shoes on shoe rack and the internal area of the bathroom cabinet
- Upstairs linen closet, including all shoes and shelving
- Bedroom two concrete floor pad, including the built-in robe and both suspended cloth storage items, including the built – in robe and suit bags
- Bedroom three concrete floor pad, including built-in robe and suit bags
- Entire staircase leading from ground to first floor
- Kitchen, including bench tops, inside kitchen cabinets, behind refrigerator and microwave oven recess
- Family room, tiled area including behind all existing furniture
- Dining room, tiled area including a small bookcase, wine rack and two camp chairs,
- Lounge room concrete floor pad
- Laundry, laundry cupboard, toilet and downstairs linen press
- Garage roof space, lifting insulation batts
- Double garage, including floor space and all items stored within the garage
- All tiled floor areas mopped twice with a bio-degradable disinfectant and all bench tops, doors and furniture wiped down.

While this was taking place the residents removed many items of clothing for washing or drycleaning. Some outfits required up to four washes to remove the smell that had impregnated the clothing.

The extensive post-fumigation treatment of the house had completely removed the smell and follow up CCWA SUMMA canister air sample showed that the dimethyldisulphide concentration was now below the level of detection of 0.3 ppb. The carpet was replaced and the tenants moved back in on June 9.

Debrief

Close cooperation between DAFWA, CBH Group, Health Department, local Shire, the property owner and tenants meant that the fumigation itself was completed in just over two weeks from the discovery of the pests. The aeration of the house took another week which is quite long and possibly due to the high concentrations of methyl bromide achieved during the two day exposure. The biggest delay in allowing the residents to return to a normal life was a result of prolonged efforts to remove the malodour which took three weeks and, combined with the cost of accommodation and cleaning, was as expensive as the actual fumigation.

We suspect that the post-fumigation steam cleaning of the carpet exacerbated the malodour problem by sucking the dimethyldisulphide molecules out of the carpet, combining it with water vapour facilitating adsorption to walls and fixtures. Treatments for insects like the khapra beetle where all belongings, fixtures and chattels must be exposed to the gas, we now recommend that, prior to the fumigation, carpets be rolled up and placed so as to allow immediate removal and disposal once the house is cleared. This may have the added advantage of not confining the dimethyldisulphide close to the concrete floor as odour can penetrate several centimetres into the concrete to be slowly released over time. Odour from the carpet underlay in walk-in robes may also have heavily contaminated the hanging clothes with dimethyldisulphide. It is possible that the carpet itself (not the underlay) could be refitted if it was carefully rolled up by professional carpet layers thus saving on replacement of the most expensive component.

The aeration fans did not do as well as we had hoped but the ozone generators were very effective. Residual ozone smelled a little like chlorine but was no worse than an indoor pool and quickly dispersed when the house was aired.

Trace Back and Forward

This incursion is interesting in that it supports the assertion that cities are major freight endpoints and are often the first landfall for invasive species[9]. Further, cities contain a far greater diversity of plant, animal and environmental conditions than elsewhere thereby increasing the probability that an exotic pest will find favourable hosts/conditions in an "agriculturally un-important" situation.

Trace-back analysis to attempt to identify the source of the infestation and guard against it occurring again was carried out with the help of AQIS. The fact that live adult beetles, which only live for two weeks, were found in the infestation indicates there must have been a food source in the container. Previous interceptions of stored grain pests have been found in microwaveable therapeutic wheat heat bags, but while a cover was found in the house, there was no evidence of any grain.

The resident's personal effects were initially consolidated in a shipping container that arrived in Fremantle, Western Australia via Hamburg and Singapore. The container had previously been used for shipments of cotton textiles, then iron and steel articles, chemical products and lastly foodstuffs. The outgoing shipping container was intercepted on arrival in Norway by AQIS officials but no khapra beetle infestation or food residues could be found.

Surveillance Trapping

Monitoring and trapping activities over two years using Tr écéStorgard traps baited with kairamone lure to attract adult beetles and a ground raw wheat germ food source for larvae will be used. These traps have been placed in the treated residence (4 traps in the garage, garage roof cavity, pantry and upstairs roof cavity), 5 neighbouring properties (1 trap in the kitchen of each house), the shipping container receival facility (12 traps), a cardboard waste recycling facility (12 traps) and a waste transfer station (10 traps). These traps were checked weekly for the first month of the program then once a month during the winter months when insect activity is low. During the warmer months of September to April the traps are inspected fortnightly except for the private residences which are checked monthly.

At the time of writing, twelve months into the trapping schedule, over 750 trap inspections have not yielded any khapra beetle. This is expected to continue for another 12 months when the eradication program will be declared a complete success.

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