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COMPARATIVE RESPONSES OF THREE PSOCID SPECIES (PSOCOPTERA: LIPOSCELIDIDAE) TO FIVE FUMIGANTS

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ABSTRACT

The responses of three different psocid species, *Liposcelis bostrychophila*, *L. decolor* and *L. paeta*, were compared when treated with the fumigants carbonyl sulfide, carbon disulfide, ethyl formate, carbon dioxide and phosphine. Eggs of psocids were exposed to one applied concentration of these gases in desiccators and mortality recorded at three different exposure periods and at three different temperatures. The three psocid species had different tolerances to each of the 5 fumigants tested and the pattern of response between species varied depending on the fumigant. Under the combinations of concentrations, times and temperatures used, the response varied widely between these psocid species. The least variability of control overall was achieved with ethyl formate. Overall, *L. paeta* was the most difficult to control.

INTRODUCTION

Complaints due to psocid infestations are currently increasing in stored commodities around the world (Turner, 1994; Rees, 1998). Large populations often develop after treatments with controlled atmosphere (CA) or fumigation. Among possible causes commonly reported are: fumigation failure, short treatment times, resistance to fumigants and selective removal of natural enemies (Pike, 1994; Santoso *et al.,* 1996; Roesli *et al.,* 1997).

A number of potential new fumigants are being currently studied for the control of stored product pests (Desmarchelier, 1998; Reichmuth, 1999). Despite the importance of psocids (Psocoptera), there is little information on their susceptibility to these fumigants. Phosphine (PH_3) has been found to be highly effective against *Liposcelis bostrychophila* (Badonnel), *L. decolor* (Pearman) and *L. paeta* (Pearman) (Nayak *et al.*, 1998). Eggs of *L. bostrychophila* were found to be more tolerant than adults to PH_3 (Ho and Winks, 1995) and to CO_2 (Leong and Ho, 1991). Weller and Beckett (in press) recently found that PH_3 at 10, 20 and 35 ppm, for 15 and 28 d, controlled populations of *L. bostrychophila*, *L. decolor*, and *L. entomophila*, at 25 and 30°C.

The aim of our research was to investigate the response of three psocid species to a range of potential fumigants so that effective application rates can be recommended for each species.

MATERIAL AND METHODS

Species tested were *L. bostrychophila*, *L. decolor* and *L. paeta*. The strain of *L. bostrychophila* was originally obtained from Gogeldrie, New South Wales, *L. decolor* from Thevenard, South Australia and *L. paeta* from Ayr, Queensland, Australia.

Eggs were exposed to one applied concentration of each fumigant in glass desiccators (Table 1). The fumigant concentrations and times were selected to give mortalities between 80 and 100%. These selections were based largely on unpublished data with the exception of CO_2, which was based on data from Leong and Ho (1991). The ethyl formate (EtF) used was laboratory grade (920 g/L); carbon disulfide (CS_2) was laboratory grade (1,263 g/L); carbonyl sulfide (COS) was cylinderized gas (98%); CO_2 was mixed from cylinderized CO_2 (100%) and air; and PH_3 was generated by addition of aluminium phosphide tablets to 5% (v/v) aqueous sulphuric acid.

Each fumigated sample consisted of 15 g of coarsely milled rolled oats compacted into a plastic or glass dish (7 cm diameter and 5 cm high) as used by Beckett (1998). The medium was conditioned in an incubator at 70% r.h. for 15 d before use. To obtain eggs for fumigation, 50 adults were isolated on a dish of media for 2 d. Duplicates of each species were exposed in the same desiccator to one applied concentration of each gas for a range of exposure times and temperatures of 15, 25 and 30ºC (Table 1). Gas concentrations were measured during the exposures by gas chromatography, within an hour of dosing and at approximately 24-h intervals, or less for the shorter exposures. The reduction in numbers of emergent nymphs was assessed.

TABLE 1
Fumigants and dosages tested

Fumigant	Concentration	Exposure times
Ethyl formate	25 mg/L	6, 12, 24, 48 hours
Carbon disulfide	12 mg/L	1, 2, 3 days
Carbonyl sulfide	15 mg/L	1, 2, 3 days
Carbon dioxide	40% (~12%O_2)	2, 3, 4 days
Phosphine	0.03 mg/L (20 ppm)	2, 3, 4 days

RESULTS AND DISCUSSION

Analysis and sorption of fumigants

The concentration of COS, CO_2 and PH_3 remained constant during all the exposure times and at all temperatures tested, indicating that for these three fumigants no significant sorption or breakdown occurred. However, the concentrations of CS_2 and EtF declined during the experiment (Figs. 1, 2). This was probably due to sorption by the medium and in the case of EtF also due to breakdown of the chemical. Decline in concentration of EtF and CS_2 was greater at 15ºC than at 25 and 30°C.

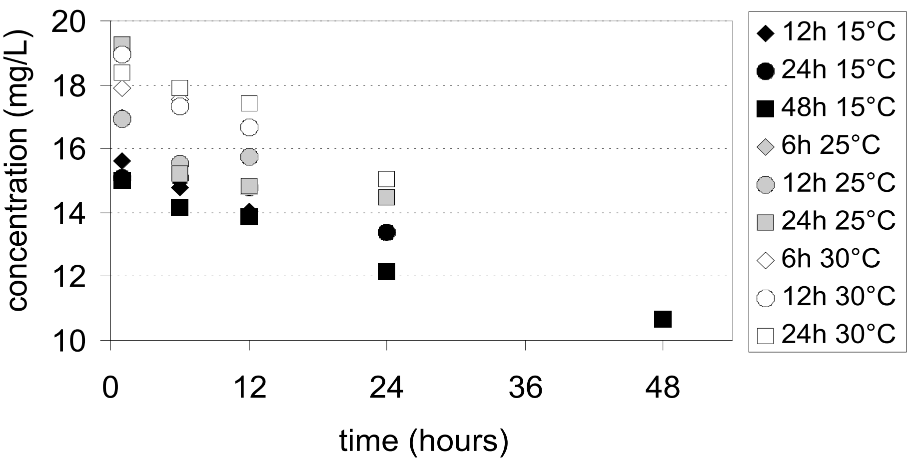

Fig. 1. Changes in ethyl formate concentration during fumigation. Ethyl formate applied at 25 mg/L.

Insect mortality

L. bostrychophila, *L. paeta* and *L. decolor* showed different tolerances to each of the 5 fumigants tested and the pattern of response varied depending on the fumigant, (Tables 2, 3). For EtF, all three species responded similarly to the combinations of concentrations, times and temperatures tested. However, *L. decolor* was the most tolerant to this fumigant at 30ºC, and *L. bostrychophila* was less tolerant than the other two species at 25ºC. For CS_2, *L. bostrychophila* was more tolerant than *L. decolor* and this latter species more tolerant than *L. paeta* at all three temperatures tested.

By contrast, *L. paeta* was the most tolerant species to all dosages and temperatures tested of the other three fumigants. *L. decolor* was the least tolerant of all three species to COS, CO_2 and PH_3. The pattern of response to these fumigants did not vary over the temperature range tested.

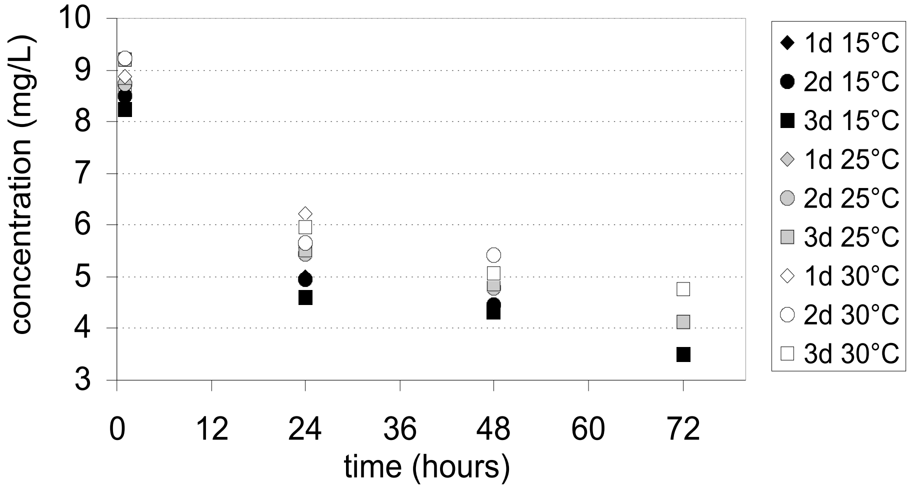

Fig. 2. Changes in carbon disulfide concentration during fumigation. Carbon disulfide applied at 12 mg/L.

TABLE 2
Percentage of progeny reduction of *L. bostrychophila* (BOS), *L. decolor* (DEC) and *L. paeta* (PAE) when treated with ethyl formate and carbon disulfide

Fumigant	Temperature (ºC)	Exposure time (hours)	% Progeny reduction BOS	DEC	PAE
Ethyl formate 25 mg/L	15	12	90 - <100	90 - <100	90 - <100
		24	100	100	100
		48	100	100	100
	25	6	90 - <100	90 - <100	90 - <100
		12	100	90 - <100	90 - <100
		24	100	100%	100%
	30	6	100	90 - <100	100
		12	100	100	100
		24	100	100	100
Carbon disulfide 12 mg/L	15	24	75 - <90	90 - <100	90 - <100
		48	90 - <100	90 - <100	90 - <100
		72	90 - <100	100	100
	25	24	75 - <90	90 - <100	100
		48	90 - <100	100	100
		72	90 - <100	100	100
	30	24	90 - <100	90 - <100	100
		48	90 - <100	100	100
		72	100	100	100

TABLE 3
Percentage of progeny reduction of *L. bostrychophila* (BOS), *L. decolor* (DEC) and *L. paeta* (PAE) when treated with carbonyl sulfide, carbon dioxide and phosphine

Fumigant	Temperature °C	Exposure time (hours)	% Progeny reduction		
			BOS	DEC	PAE
Carbonyl sulfide 15 mg/L	15	24	75 - <90	75 - <90	<75
		48	90 - <100	90 - <100	<75
		72	90 - <100	100	75 - <90
	25	24	75 - <90	90 - <100	<75
		48	90 - <100	100	90 - <100
		72	100	100	90 - <100
	30	24	90 - <100	90 - <100	75 - <90
		48	90 - <100	100	90 - <100
		72	100	100	90 - <100
Carbon dioxide 40% (12% O_2)	15	48	75 - <90	90 - <100	<75
		72	75 - <90	90 - <100	75 - <90
		96	90 - <100	100	90 - <100
	25	48	90 - <100		75 - <90
		72	90 - <100	100	90 - <100
		96	90 - <100	100	90 - <100
	30	48	90 - <100	90 - <100	75 - <90
		72	90 - <100	100	90 - <100
		96	90 - <100	100	90 - <100
Phosphine 0.03 mg/L (20 ppm)	15	48	75 - <90	75 - <90	<75
		72	75 - <90	90 - <100	<75
		96	90 - <100	90 - <100	<75
	25	48	90 - <100	90 - <100	<75
		72	90 - <100	90 - <100	<75
		96	90 - <100	100	<75
	30	48	90 - <100	100	<75
		72	90 - <100	100	75 - <90
		96	90 - <100	100	75 - <90

These results indicate that within the species and strains tested, *L. paeta* was the most tolerant species to PH_3, COS and CO_2, *L. bostrychophila* was the most tolerant species to CS_2 and *L. decolor* was the most tolerant to EtF for the combinations of concentrations, times and temperatures tested. However, there can be just as much variation in response between strains of a given species as between individual species as observed by Weller and Beckett (in press). Therefore, in order to control psocids it maybe necessary to establish which species, and possibly which strains, are present in an infestation and apply the correct fumigant at the correct rate, although it would probably be sufficient to ensure that recommended applications cover the most tolerant species.

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