Response of the pea weevil *Bruchus pisorum* (L.) to phosphine

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Abstract

Two field strains of *Bruchus pisorum* (L.) infesting peas were exposed to the fumigant phosphine at two fixed concentrations of 120 g/L and 240 g/L, and one decaying from 1.5 g/m^3, at 25 and 15°C. Treatment times were 5, 10, 14 and 21 days. Emergence after treatment was assessed at 2–3 weeks, 6–8 weeks and again at 12 months. Results indicate that further emergence of adults from fumigated peas occurred after 14 days exposure for all treatments in one strain and after 5 days exposure to 120 g/L for the other strain. All the emerged adults were dead when inspected. Dissection of subsamples of 100 peas indicated that survival was greatest in the pupal stage with increased survival in adult and larval stages at 15°C. Results indicate that to ensure control of all stages longer rather shorter exposures are desirable.

Introduction

Recommendations for phosphine fumigation of field peas for control of the pea weevil *Bruchis pisorum* (L.) in Australia are based largely on the biology of the pest and an assumption that its tolerance of phosphine is similar to that of some of the other stored product bruchids. The aim of this study was to examine the validity of these recommendations and to establish dosages needed to control the pea weevil in stored field peas.

Materials and Methods

Infested peas from two areas of Australia were used. One was supplied by the Department of Agriculture, Victoria and referred to as 'Strain A' while the other, 'Strain B', was supplied by the Department of Agriculture, South Australia. Both strains were from plots of untreated peas to ensure a high level of infestation and were machine harvested. Samples of each strain were placed in position on grids by means of contact adhesive, and X-rayed at 30 kV, 3 mA for 2 seconds. Examination of the radiographs indicated the level and stages of infestation present. The infested peas were divided and packed in porous paper parcels each weighing 800 g. These were placed into chambers (Fig. 1) through which conditioned air was passed. Both strains, heavily infested with all stages of the pea weevil *B. pisorum* (L.), were exposed to constant concentrations, 120 µg/L and 240 µg/L. Samples were exposed at two temperatures, 25 and 15°C, for periods of 5, 10, 14 and 21 days.

Constant concentrations were applied by means of mass-flow controllers, a diaphragm pump, and a cylinder of compressed gas containing 1 g/m^3 phosphine in nitrogen (Fig. 1). Air from the pump and phosphine from the gas cylinder were controlled through two mass-flow controllers so that when the output from each was blended the appropriate concentration was produced. The resultant gas mixture was passed through distilled water in a bubbler held at 15°C in a water bath. The saturated mixture was then warmed to 25°C thus lowering the relative humidity to 57%. This equates to 10–11% moisture content for peas. The gas was then passed to a manifold where it was divided into equal flows one for each chamber. The moisture content of the peas supplied was not measured.

A concentration of 1.5 g/m^3 phosphine was applied to a third set of samples and allowed to decay during the experiment in an attempt to simulate a field exposure. The samples were placed in a glass aspirator of 20 L volume (Fig. 2). Apart from absorption and chemical breakdown of phosphine, to simulate gas loss, gas was allowed to diffuse through two 6 mm holes at the top of the chamber. Further gas loss occurred when samples were removed from the chamber at the end of each exposure period. The phosphine was injected into the sealed chamber through a septum at the top and the gas mixed by means of a small magnetically driven fan at the base of the chamber for 5 minutes at the beginning of the exposure.

Concentrations applied were checked by means of gas chromatography using the response of a flame photometric detector compared with the response of prepared gas standards. These were prepared by means of volumetric dilution of a high concentration phosphine source analysed with a Gow-Mac gas density balance. Samples of peas were removed at the end of each exposure period, transferred from the porous paper parcels into glass jars, sealed with black filter paper and held at 25°C and 57% r.h. Each sample was sieved at 2 weeks or at the end of exposure, whichever was the longer, and again at 6–8 weeks and 12 months. Adults were assessed as alive or dead, numbers recorded, and adults removed. In addition, at 14 days or the end of exposure and again at 6–8 weeks a subsample of 100 peas was selected from each treatment sample and dissected to assess the effect on immature stages.

Results

The X-ray plates indicated that the two strains of weevil were at a slightly different stage of development. Strain B being further advanced in development and hence containing a much higher proportion of the pupal and adult stages. Conversely, Strain A revealed a higher proportion of early larval stages and no adults. This was confirmed by the dissection of the subsamples (Table 1) which showed no adults, 13 pupae and 23 larvae for Strain A, as against 3 adults, 18 pupae and only 8 larvae in Strain B. In addition, the sieving done at 14 days (Table 2) showed no adult emergence from the controls of Strain A, whereas in Strain B, 38 adults had emerged from the control sample.

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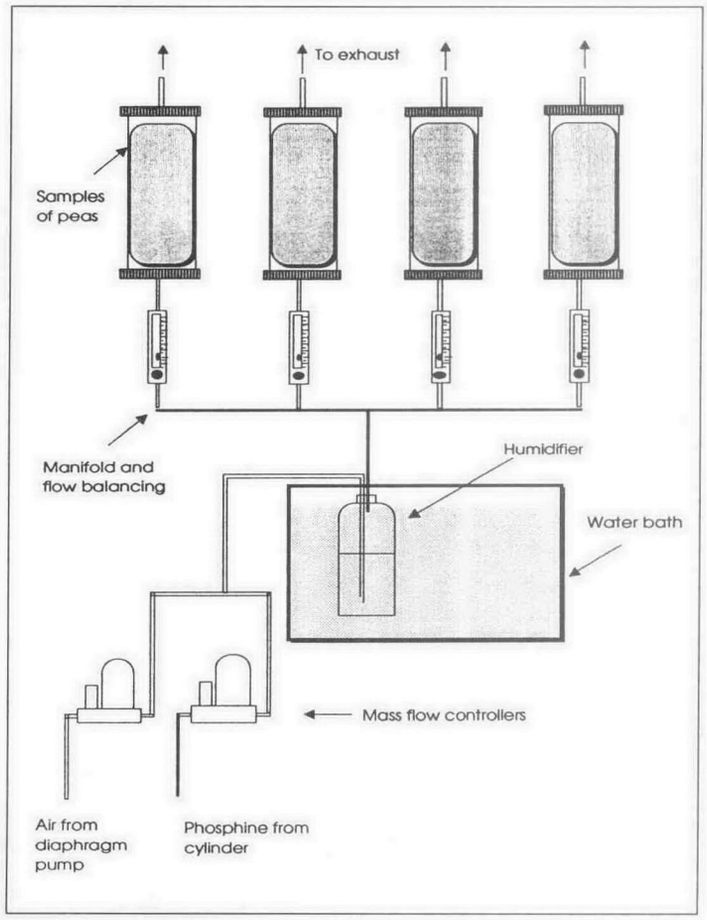

Fig. 1. Apparatus used to expose samples of infested peas to fixed concentrations of phosphine.

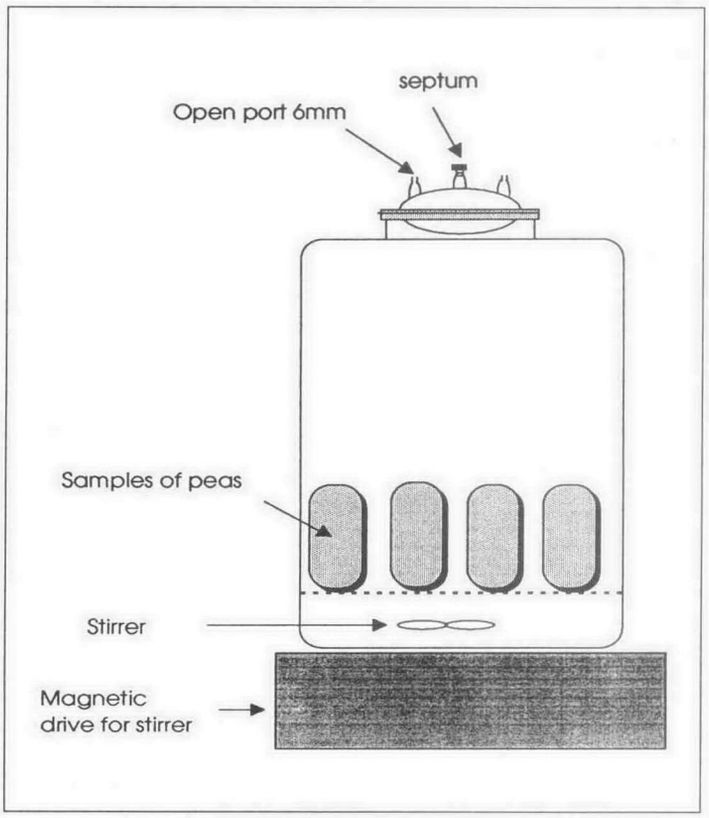

Fig. 2. Apparatus used to dose sample of peas with a decaying concentration of phosphine.

Table 1. Developmental stages of *B. pisorum* (L.) present in samples of 100 control peas dissected 14 days from start of exposure

Strain	Larvae		Pupae		Adults	
	Live	Dead	Live	Dead	Live	Dead
A	5	18	5	8	0	0
B	3	5	12	6	2	1

An estimate of the numbers of pea weevil exposed in each 800 g sample, was obtained from the radiographs and average weight of peas dissected. These data, combined with average control mortality, gave an indication of the number of live insects treated in each sample (Table 4). The sieving results, (Table 2.) which looked only at emergence, show no survival of emerged adults at any treatment for either strain, i.e. all emerged adults were dead when inspected. However, since all adults were removed after sieving and again at subsequent sievings it would appear that for Strain B further emergence occurred up to 14 days for all dosage combinations and for 21 days exposure at 120 µg/L and a treatment temperature of 25°C. Strain A appeared to be controlled by a 10-day exposure, there being further emergence of adults at 5-day exposures for this strain at 120 µg/L but none at 240 µg/L. It may be that this apparent emergence of adults is due to adults being killed just before emergence and, with desiccation, falling out on subsequent sieving, or that they were seriously affected by their exposure and died during, or on, emergence. However, the condition of stages present in the dissected material (Table 3) showed that survival within the pea was present up to 6 weeks after commencement of exposure. This was most apparent in the pupal stage. In addition, the reduced efficacy of phosphine at the lower temperature of 15°C is indicated by survival of the adult and larval stages.

The natural mortality of emerged adults was high for both strains, 13% for Strain A and 33% for Strain B. This mortality was on top of approximately 66% mortality for all stages present in the infested peas. This very high level of mortality during maturation of the pea weevil would seem to be caused by storage and handling alone. It is not possible to say what effect these conditions had on the results of this experiment.

Discussion

The data indicate that some survival of *B. pisorum* (L.) to a phosphine fumigation is possible after 14 days exposure. More importantly, it appears that this species follows the same pattern as other stored product pests in that the pupal stage appears to be the most tolerant stage of development. It would seem then that fumigating as early as possible in the life-cycle, would increase the probability of a successful fumigation and have the added advantage of minimising damage done to the peas by any infestation present. The emergence of a number of adults from Strain B between the seiving at 2 weeks and the subsequent examinations at 6–8 weeks and 12 months would suggest that some pupae survived and developed to adults. Since none of these emerged adults was found alive, whether they died because of natural mortality, handling stress induced by the examination of each sample or because of the chronic effects of phosphine cannot be said.

There are two possible reasons for the substantial difference in response by the two strains. Firstly, Strain A could be generally more susceptible to phosphine and hence at the dosages applied more easily controlled. Secondly, since Strain A was at an earlier stage of development, the predominant stage being fumigated would have been the larvae and this stage is presumably easier to control. However, there was a proportion

Table 2. Incubation results for field peas infested with *B. pisorum* (L.) exposed to phosphine for two fixed and one decaying concentration at two temperatures. All emerged adults in the treatments were dead.

Assessment	Exposure											
	5 days			10 days			14 days			21 days		
	2	6	52 weeks	2	6	52 weeks	2	6	52 weeks	2	6	52 weeks
120 µg/L 25°C												
Strain A	0	2	1	0	0	0	0	0	0	0	0	0
Strain B	21	1	5	17	2	7	24	1	3	12	0	1
240 µg/L 25°C												
Strain A	0	0	0	0	0	0	0	0	0	0	0	0
Strain B	15	2	2	11	0	2	14	0	2	20	0	0
120 µg/L 15°C												
Strain A	0	1	0	0	0	0	0	0	0	0	0	0
Strain B	24	2	2	17	2	8	0	0	2	11	0	0
240 µg/L 15°C												
Strain A	0	0	0	0	0	0	0	0	0	0	0	0
Strain B	14	0	4	25	1	5	23	0	2	16	0	0
1.5 g/m^3 25°C	decaying to 0.005 g/m^3 at 21days											
Strain A	0	0	0	0	0	0	0	0	0	0	0	0
Strain B	17	0	2	12	0	2	13	0	1	12	0	0
1.5g/m^3 15°C	decaying to 0.004 g/m^3 at 21days											
Strain A	0	0	0	0	0	0	0	0	0	0	0	0
Strain B	12	0	2	12	0	1	10	1	1	14	1	0

Table 3. Survival of internal stages of *B. pisorum* (L.) in peas exposed to phosphine at 120 and 240 µg/L and 1.5 g/m^3 decaying to 0.005 g/m^3 concentration at two temperatures. Samples of 100 peas from each treatment were dissected two or three weeks and six weeks after start of exposure.

Assessment	Larvae				Pupae				Adults			
	Exposure (days)											
	5	10	14	21	5	10	14	21	5	10	14	21
25°C												
120 µg/L												
2 weeks	0	0	0	0	5	1	2	2	0	0	0	0
6 weeks	0	0	0	0	0	1	0	0	0	0	0	0
240 µg/L												
2 weeks	0	0	0	0	6	0	1	0	0	0	0	0
6 weeks	1	0	0	0	1	1	0	0	0	0	0	0
1.5 g/m^3												
2 weeks	0	0	0	0	0	0	0	0	0	0	0	0
6 weeks	0	0	0	0	0	1	0	0	0	0	0	0
Total 25°C	1	0	0	0	12	4	2	2	0	0	0	0
15°C												
120 µg/L												
2 weeks	1	0	3	0	8	1	3	2	1	0	0	1
6 weeks	0	0	1	0	0	2	0	0	3	2	2	0
240 µg/L												
2 weeks	1	0	0	0	7	2	0	0	1	0	0	0
6 weeks	1	0	0	0	1	2	0	0	0	1	0	0
1.5 g/m^3												
2 weeks	0	1	0	0	0	1	0	0	0	0	0	0
6 weeks	0	2	0	0	0	1	0	0	1	0	0	0
Total 15°C	3	3	4	0	16	9	3	2	5	2	2	1

Table 4. Estimated number of pea weevils, *B. pisorum* (L.), treated in each 800 g sample of peas

Strain	No of peas X-rayed	% infested	Average weight of 100 peas	No. of insects in 800 g sample	
				Total	Alive
A	822	46	22.7g ± 1.0	1620	593
B	837	36	15.1 g ± 0.5	1800	498

of pupae present in both strains which suggests the first possibility could be the case. The implications of this are that a fairly broad range of tolerance to phosphine may exist in the field. How this range of tolerance arose is open to speculation. However, to ensure disinfestation of all strains present in the field the underlying need for extended exposure when fumigating with phosphine remains, regardless of what developmental stage is present, since the absence of the pupa cannot be guaranteed.

As far as recommendations for phosphine treatment of *B. pisorum* (L.) are concerned there is no evidence from the response of these two strains to support a reduction in time of exposure for a treatment. In addition, the use of gastight enclosures is essential to retain the gas, or a method of application of the fumigant, such as SIROFLO®, which sustains a lethal concentration for the required time. The emergence of one adult, at between 6 weeks and 12 months, after 21 days exposure may suggest an even longer exposure than 14 days would be desirable.

Acknowledgment

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