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Efficacy of reduced risk insecticides on penetration into jute and polyethylene bags by *Lasioderma serricorne* (F.) (Coleoptera: Anobiidae)

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ABSTRACT

This study investigated the efficacy of DE, pea protein, methoprene, pyrethrins and DEET at label rates to reduce penetration of stored-product insect *Lasioderma serricorne* (F.) (Coleoptera: Anobiidae) to jute and polyethylene woven bags. The survival of eggs and young larvae of *L. serricorne* were measured. The insecticides caused 27–67% mortality of eggs and larvae. There was no difference between insecticides, but all caused higher mortality than controls. A second test measured the ability of adults to penetrate the jute and polyethylene materials treated with the various insecticides. After 24 h, approximately 85% of adults *L. serricorne* had penetrated through the untreated jute and polyethylene materials. Fewer insects penetrated through the treated jute materials; DEET (12.5 ± 4.8%), pyrethrins (20 ± 4%), methoprene (30 ± 4%), pea protein (42.5 ± 4.8%), and DE (52.5 ± 4.8%). While, the percentage of adults *L. serricorne* penetrated the treated polyethylene materials were; DEET (20 ± 4%), pyrethrins (35 ± 6.4%), methoprene (50 ± 4%), pea protein (62.5 ± 4.8%), and DE (62.5 ± 4.8%). A third test measured the ability of insecticides to prevent the infestation of flour in jute and polyethylene bags. Fewer insects emerged from flour in jute and polyethylene bags treated with insecticides. All insecticides reduced infestation from 49 to 83%, with DEET being the most effective.

1. Introduction

Stored-product insects can be put into one of two groups with respect to their ability to penetrate packaged goods; penetrators that can chew into packages and invaders that only can enter packages through existing holes (Newton, 1988; Highland, 1991; Mullen et al., 2012). The products stored in warehouses or retail stores are infested by stored-product insects causing hidden infestations. The type of packaging greatly effects the insect infestation of finished products. There are several types of packaging material used; paper, plastic, aluminium foil or jute. Some materials, such as polymers and paperboard are used in high-value products such as snack foods, and are excellent at preventing insects from entering into packages, but are costly. Jute or polyethylene are used around the world to bag seed and botanicals, however, they are ineffective at preventing insects from entering bags.

The cigarette beetle, *Lasioderma serricorne* (F.) (Coleoptera: Anobiidae), develop on a wide variety of foods: grain, spices, botanicals, processed foods and tobacco, and are a pest at several locations in the storage chain: primary storage, processing and retail (Howe, 1957; Tawfik et al., 1984; Awadallah et al., 1990; Arbogast et al., 2002; Rees, 2004; Abdelghany et al., 2010). Larvae cause the most damage to stored products, as adults do not feed. Both larvae and adults can penetrate packaging by chewing (Highland, 1991; Riudavets et al., 2007; Mullen et al., 2012).

Insecticides and repellents can be used with packaging materials to reduce insect infestation (Highland, 1991; Hou et al., 2004; Chung et al., 2011; Mullen et al., 2012). These compounds were chosen because they have low mammalian toxicity (Snelson, 1987). Pyrethrins are the most widely used botanical insecticide. They are extracted from chrysanthemum (*Chrysanthemum cinerariaefolium* Vis.) flowers (Casida, 1980; Matsuda et al., 2005). Pyrethrins are both toxic and repellent (Snelson, 1987) and are often synergized

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Table 1
Mean mortality (%, ±SE) of eggs and larvae of *Lasioderma serricorne* (±SEM) when held on jute or polyethylene pieces treated with different products after 5 days. Ten eggs or larvae were used separately in each Petri dish in each treatment, (n = 4).

Products	Dose (g/m^2)	Mortality (%)[a]			
		Eggs		Larvae	
		Jute	Polyethylene	Jute	Polyethylene
DEET	0.02	57 ± 11a	47 ± 11a	57.5 ± 16.5a	67.5 ± 16.5a
Pyrethrins	0.05	50.0 ± 4.8a	40.0 ± 4.0a	60.0 ± 4.0a	50.0 ± 4.0a
Methoprene	3 × 10-5	47.5 ± 6.3a	50.0 ± 4.0a	40.0 ± 9.1a	32.5 ± 4.7a
Pea flour	25	42.5 ± 11.0a	32.5 ± 11.0 ab	47.5 ± 11.0a	37.5 ± 11.0a
DE	5	27.5 ± 4.7 ab	32.5 ± 6.2a	37.5 ± 4.7a	47.5 ± 4.7a
Water (control)	625	7.5 ± 4.7bc	5.0 ± 2.8c	5.0 ± 2.8b	5.00 ± 5.0b
70% Ethanol (control)	625	2.5 ± 2.5c	7.5 ± 4.7bc	5.0 ± 2.8b	0.00 ± 0.00b
Untreated (control)	0	2.5 ± 2.5c	2.5 ± 2.5c	2.5 ± 2.5b	0.00 ± 0.00b

Three-way ANOVA, bags: $F_{1,96} = 0.70$, $P = 0.404$; insecticides: $F_{7,96} = 37.00$, $P < 0.001$; life stages: $F_{1,96} = 0.91$, $P = 0.34$.
[a] For a given column, different letters indicate that the materials were significantly different (Tukey's MRT $P < 0.05$).

with piperonyl butoxide (PBO). Methoprene is a synthetic juvenile hormone analog that is used commercially against many insects (Oberlander and Silhacek, 2000). It is very effective against immature stages, and can cause reduced fertility in adults in some species (Oberlander et al., 1997; Chanbang et al., 2007), but not all species (Wijayaratne et al., 2012).

There are several other insecticides that could work effectively with packaging to reduce infestations. Diatomaceous earth (DE) is registered for use on stored wheat, and is a natural product composed primarily of the remains of fossilized diatoms. The label rates range from 100 to 5000 ppm depending on the formulation, physical properties of grain and target species (Korunic, 1997; Fields and Korunic, 2000). DEET *N,N*-diethyl-3-methylbenzamide is one of the most potent and widely used insect repellents and there is no evidence showing DEET to be developmentally toxic, or mutagenic to mammals (Anonymous, 1998). Pea protein is repellent and toxic to several stored-product insects (Fields et al., 2001; Hou and Fields, 2003).

The objective of this study was to determine if reduced-risk insecticides; DE, pyrethrins, methoprene, pea protein and DEET applied to two common bagging materials; jute and polyethylene could protect the commodities either by killing or repelling the stored-product insect *L. serricorne*.

2. Materials and methods

2.1. Test insects

The cigarette beetle, *L. serricorne*, used in this study was maintained on 95% white wheat flour and 5% (by weight) brewer's yeast at 30 °C and 60% R.H. Adults (<1 d after emergence) were collected from the tops of the jars, eggs (2-d old), and young larvae (5-d old larvae after egg laying). Eggs were sieved from the diet using a 250-μm mesh screen. The young larvae were sieved from the jars with a 1-mm mesh screen. All experiments were carried out at 30 ± 1 °C and 60 ± 10% R.H. in the dark. There were 4 replicates for each experiment.

2.2. Treatment of jute and polyethylene material

Five products were tested for their repellency and toxicity on jute and polyethylene bags, at approximately their label rates. Pea protein at 25 g/m^2 (protein-rich flour from *Pisum sativum* L., Progress Protein; 60% protein, 30% starch, and 7% moisture content, Nutri-Pea Limited, Saskatoon, SK), diatomaceous earth at 5 g/m^2 (Protect-It®, 90% DE, 10% by weight of silica gel, Hedley Technologies Ltd, Mississauga, Ontario, Canada), methoprene at 3 × 10^{-5} g/m^2 (Diacon II®, 33.6% *s*-methoprene, Central Life Sciences, Schaumburg, Illinois, USA), pyrethrins at 0.05 g/m^2 (Scotts® Eco-sense™ with 0.5% pyrethrins without PBO, Scotts Canada Ltd, Mississauga, Ontario, Canada), DEET at 0.02 g/m^2 (OFF, DEEP WOODS with 25% DEET, diethyl-m-toluamide, S.C. Johnson & Son Inc., Brantford, Ontario, Canada), were used to estimate their effectiveness on the penetrating ability of *L. serricorne*. All dosages are given in terms of active ingredients, except pea protein and DE. Methoprene and pyrethrins were diluted with water. DEET was mixed with 70% ethanol. DE and pea protein were applied as powders. Woven jute or polyethylene material were treated with either 625 g/m^2 of water to serve as the control for methoprene and pyrethrins, or 625 g/m^2 of 70% ethanol to serve as the control for DEET. Spraying jute or polyethylene with methoprene, pyrethrins, DEET, 70% ethanol and water was carried out under a fume hood using an artist's brush (Paasche Airbrush Company, Chicago, USA).

2.3. Contact test

Ten eggs or 10 larvae of *L. serricorne* were placed on the surface of the treated sheets of jute and polyethylene (70 mm × 70 mm) with 5 g diet in a Petri dish (100 × 15 mm). Four sheets of jute and polyethylene were laid out in a single layer on a wax sheet. Enough product was placed in the air brush to treat the 8 sheets. For DE and pea protein, we dusted the powders on to each sheet of jute and polyethylene. The number of live larvae was noted after 5 days.

2.4. Penetration test

Two glass jars (909 mL each) were joined together and jute or polyethylene sheets were stretched between the two jars. Ten adults of *L. serricorne* were placed in the top jar. The number of insects penetrating the sheets after 12, 24, 48, 72 and 96 h was noted. Sheets of jute and polyethylene were sprayed with the various compounds as above.

2.5. Bag test

We tested the ability of the insecticides to prevent insects from penetrating jute and polyethylene bags. Two-hundred grams of white wheat flour was placed into small jute and polyethylene bags (25 × 23 cm). Bags were treated (as above) on the outside, allowed to dry for 15 min and filled with Twenty adults of *L. serricorne* were released into boxes (12 × 21 × 34 cm). After 5 weeks, flour in the bags was sifted, and the number of adults noted.