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FULL LENGTH ARTICLE

Evaluation of the toxicological effect of bean flour on the mortality and population dynamics of two storage mites

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Abstract A laboratory study was carried out to demonstrate the efficiency of bean flour in the control of two storage mites: *Tyrophagus putrescentiae* (Schrank, 1781) and *Aleuroglyphus ovatus* (Troupeau, 1878) fed on two dried Chinese herbs: coix seed (*Coix lachrymal-jobi*) and Chinese hawthorn (*Crataegus pinnatifida*). Five concentrations of bean flour (0%, 0.01%, 0.1%, 1% and 10%) were used at 25 °C and 85 ± 5% relative humidity (RH) under darkness. The results indicated that the controlling effect of bean flour on *T. putrescentiae* was higher than that on *A. ovatus* and became more noticeable when its concentration was increased. Low dose of bean flour (0.01%) generally had no toxic effect on *T. putrescentiae* and *A. ovatus* when they fed on *C. lachrymal-job* and *C. pinnatifida*. Mortalities of *T. putrescentiae* on *C. pinnatifida* varied from 15% to 40% and from 26% to 61% on *C. lachrymal-job* due to the use of 0.1% of bean flour. Moreover, in the case of *A. ovatus*, the mortalities ranged from 6% to 26% and from 15% to 51% on *C. pinnatifida* and *C. lachrymal-job*, respectively. After 28 days, the concentration of 1% bean flour caused 81% and 52% mortalities of *T. putrescentiae* and *A. ovatus* on *C. pinnatifida* and 92% and 69% on *C. lachrymal-job*. Addition of bean flour at 10% on *C. pinnatifida* and *C. lachrymal-job* killed all individuals of *T. putrescentiae* and *A. ovatus*.

The results showed also that population dynamics of *T. putrescentiae* and *A. ovatus*, which is explained by the rate of increase (*r* values) on *C. pinnatifida* and *C. lachrymal-job* did not change considerably at 0% and 0.01% concentrations of bean flour. On the other hand, *r* values of *T.*

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putrescentiae and *A. ovatus* reread on *C. pinnatifida* and *C. lachrymal-job* sharply decreased at other concentrations of bean flour (0.1%, 1% and 10%) after 21 days. It can be concluded that 1% of bean flour is a good concentration to control *T. putrescentiae* after 28 days on *C. pinnatifida* and *C. lachrymal-job*, but it is not good enough in the case of *A. ovatus*.

1. Introduction

Storage mites (Acari: Astigmata) are harmful pests and greatly distributed in the countries, which are characterized by high humidity climate (Hubert and Pekár, 2009). There are many reports which showed that storage mites such as *Tyrophagus putrescentiae* (Schrank. 1781) and *Aleuroglyphus ovatus* (Troupeau, 1878) can affect various stored products, including flour, dried fruits, vegetables, grains, seeds, and ornamental and medicinal plants (Hughes 1976; Hubert and Pekár, 2009; Stará et al., 2011; Hubert et al., 2013). Attack of storage mites can cause huge losses in the quality and safety of stored products due to the accumulation of fungi mycotoxins and mite residues, which are derived from their activities (Hubert et al., 2003; Hubert et al., 2004; Nesvorna et al., 2012). Moreover, these mites can also lead to hazardous health problems for humans such as allergens, respiratory disease and atopic dermatitis (Franzolin et al. 1999; Colloff, 2009). It was recorded by Hubert et al. (2013) that the storage mite threats are whispered to be serious when their population densities are high (> 1000 mites/kg stored product).

There are many methods that have been applied to control storage mites. The use of physical techniques, which generally depends on the changing of temperature and humidity of dried products stores, faced some limits to apply them. For example, the farmers cannot professionally manage the temperature and humidity, and this may cause high increases in the population of storage mites (Hubert et al., 2006a). Chemical control of storage mites using different acaricides is an effective and economical method but they havelegal limits due to their harmful effects on human health (Sanchez-Ramos and Castanera, 2001; Collins, 2006). Moreover, the resistance of storage mites can be increased as a result of continuous addition of chemical pesticides (Zettler and Arthur 2000; Hubert et al., 2007). For that reason, it is very important to investigate good and suitable methods to control and decrease the population of storage mites without causing harmful effects on humans.

Recently, many investigations have been focused on the development of new natural pesticides to control stored product pests. For example, botanical pesticides such as protein-enriched pea flour (*Pisum sativum*) showed high efficiency in controlling stored grain pests (Hou and Fields 2003; Fields 2006). It was mentioned by Hubert et al. (2006) and Hubert et al. (2007) that the application of bean flour (*Phaseolus vulgaris*) caused significant decreases in the population of storage mites. The effect of legume flour has been well evaluated on stored product insects (Fields et al. 2001; Hou and Fields 2003; Fields 2006). However, few studies were conducted to evaluate the toxic potential of bean flour (*P. vulgaris*) as an acaricide on storage mites (Hubert et al., 2006; Hubert et al., 2007; Hubert and Pekár, 2009). To the best of our knowledge, no study has been done to examine the efficiency of bean flour as an antifeedant against storage mites, which infested dried Chinese herbs. Therefore, the current study was conducted to estimate the toxic influence of different bean flour doses on the mortality and population dynamics of two storage mites (*T. putrescentiae* and *A. ovatus*) fed on two dried Chinese herbs (*Crataegus pinnatifida* and *Coix lachrymal-jobi*).

2. Materials and methods

2.1. Bean flour and Chinese herbs

The bean flour (*P. vulgaris* L.), which was used as an antifeedant in the current study was obtained from the College of Horticulture at Huazhong Agricultural University (HZAU), Wuhan, China. Seeds of bean were dried at 50–60 °C for 48 h, ground to powder with an electric mill, and then stored in a polyethylene bag for future usage. Two Chinese herbs, coix seed (*C. lachrymal-jobi*) and Chinese hawthorn (*C. pinnatifida*) were also collected from the College of Plant Science and Technology at HZAU. The herbs were dried at 50–60 °C for 48 h and then crushed to small pieces to use them as diets for storage mites.

2.2. Storage mites

Two stored product mites, *T. puterscentiae and A. ovatus* were used in our research and collected from the College of Plant Science and Technology at HZAU. The mites were mass-reared according to the method of Hubert et al. (2006). In brief, *T. puterscentiae* and *A. ovatus* were placed in glass flasks (volume 1000 ml) containing a rearing diet which consisted of 45 g oat flakes, 45 g wheat flour and 10 g yeast. After that, the flasks were covered by muslin and kept in an incubator at 25 °C and 85 ± 5% RH in the dark. *T. puterscentiae* and *A. ovatus* were transferred individually to other rearing flasks contained herbs for one week for the acclimation process before beginning the experiment.

2.3. Experimental design

A factorial experiment with three factors (Chinese herbs, storage mites and bean flour concentrations) was set up in a randomized complete block design with ten replicates per treatment. The experiment was carried out in 100 ml plastic cups, which contained 5 g of each Chinese herb and 50 adults of *T. puterscentiae* and *A. ovatus*. Bean flour was used at five mass concentrations: 0%, 0.01%, 0.1%, 1%, and 10% (w/w). The previous concentrations of bean flour were well shaken individually with *C. pinnatifida* and *C. lachrymal-job* before the experiment start. The experimental cups were kept in an incubator at 25 °C, 85 ± 5% RH in the dark. The mortalities of *T. puterscentiae* and *A. ovatus* adults were estimated after 7, 14, 21 and 28 days. However, the population growth of