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Effect of suboptimal temperatures and sublethal CO_2 levels on multiplication of *Tribolium castaneum* (Coleoptera: Tenebrionidae), alone or competing with *Cryptolestes ferrugineus* (Coleoptera: Cucujidae)

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Abstract

Groups of adults of *Tribolium castaneum* alone, or in combination with adults of *Cryptolestes ferrugineus*, were exposed to suboptimal temperatures (15°C, 20°C, and 25°C) and sublethal CO_2 levels (2%, 5%, and 10%) in dry (12%, wet mass basis) and damp (15%, wet mass basis) stored wheat in the laboratory, to investigate effects on population size. The mean adult numbers in single- and mixed-species tests were positively correlated with higher temperature and moisture content and negatively correlated with higher CO_2 levels. Adult numbers in single- and mixed-species tests were lower at sublethal CO_2 levels compared to ambient CO_2 levels at all the test temperatures and decreased in dry grain compared to damp grain. Although, a specific trend was not observed in population inhibition between mixed-species and single-species tests, overall the adult populations of *T. castaneum* were reduced in the presence of *C. ferrugineus*. A mathematical model was derived to predict the size of adult populations of *T. castaneum* alone, or in the presence of *C. ferrugineus* considering all the variables in this study. The model had an R^2 value of 0.72 but needs to be validated and refined with field data.

Keywords: *Tribolium castaneum*; *Cryptolestes ferrugineus*; Temperature; CO_2; Populations

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1. Introduction

The red flour beetle, *Tribolium castaneum* (Herbst) and the rusty grain beetle, *Cryptolestes ferrugineus* (Stephens) are the two most common and economically important beetle species in stored grain on the farm in the Canadian prairies and they frequently occur together (Sinha and Watters, 1985; White and Loschiavo, 1985; Madrid et al., 1990). *Tribolium castaneum* can cause much more damage to stored wheat because adults are about 10-fold heavier than *C. ferrugineus* adults (White, 1995). The two species have been extensively studied individually at optimum (30–32°C) (Howe, 1965) and higher temperature ranges. Population variation due to interaction between these two species at naturally produced CO_2 concentrations of 2–10% and cool temperatures of 15–25°C has not been investigated. These temperature ranges are generally observed in stored grain in the Canadian prairies in autumn, falling from temperatures as high as 35°C at harvest. CO_2 levels of 2–10% are biologically producible concentrations caused by respiration of grains, insects, molds and microorganisms (Muir et al., 1985; Sinha et al., 1986). The elevated levels of CO_2 would increase respiration, cause spiracles to dilate permitting desiccation, and acidify haemolymph (Nicolas and Sillans, 1989).

Population growth of *T. castaneum* at suboptimal conditions could be incorporated into integrated, holistic simulation models to improve the detection and management of insect populations and act as an aid in decision making by pest management experts. A number of population dynamics and pest management models have already been developed for stored grain pests (Throne, 1995), and Jayas (1995) has reviewed a number of moisture, gas, and heat-transfer models which simulate granary conditions and predict the conditions that would affect insects in bulk grain.

The objectives of the study were to determine the effect of suboptimal temperatures (15°C, 20°C, and 25°C), sublethal CO_2 levels (2%, 5%, and 10%) in dry (12%, wet mass basis) and damp (15%, wet mass basis) wheat, on adult populations of *T. castaneum* reared as a single species or in combination with *C. ferrugineus*. A mathematical model to predict the adult population of *T. castaneum*, as a single species and in combination with *C. ferrugineus* was derived by considering all the variables in the experimental study. A previous report on the interspecific effects on C. *ferrugineus* populations was given by Hulasare et al. (2003).

2. Materials and methods

2.1. Beetle species, sex ratio, and food substrate

Tribolium castaneum were reared on wheat flour plus brewer's yeast (19:1, wt:wt) and *C. ferrugineus* were reared in laboratory cultures on cracked wheat plus wheat germ (19:1, wt:wt), all maintained at 30 ± 1°C and 70 ± 5% relative humidity (r.h.). The cultures of *C. ferrugineus* and *T. castaneum* had been reared in the laboratory for 9 years.

The sex ratio of adults of *T. castaneum* was determined by microscopically identifying the sex of 300 pupae based on the form of the genital papillae in Tenebrionidae (Halstead, 1963) and that of *C. ferrugineus* on the basis of the shape of the mandibles in a sample of 300 adults (Rilett, 1949).