Simulation model of the red flour beetle in flour mills

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Abstract

Red flour beetle (*Tribolium castaneum*) is one of the most common insect pests infesting wheat flour mills (Toews et al. 2006). Structural treatments such as methyl bromide, sulfuryl fluoride and heat, are used to control the red flour beetle. The structural treatments do not provide any residual action and thus, any surviving insect stages can rebound rapidly depending on the temperature. In addition, the distribution of the fumigant or heat-treatment in the facility can result in different mortality rates for different floors or regions of the mill. Simulation models can be used to develop optimal integrated pest management strategies (Thorpe et al., 1982; Longstaff, 1988; Hagstrum and Throne, 1989; Flinn et al., 1997). Models developed for the flour beetle in stored grain have been useful for predicting population trends (Hagstrum and Flinn, 1990). Our objective was to develop a model for the red flour beetle in wheat flour mills that could be used to predict the effects of various structural treatments and subsequent population rebound. Currently, heat-treatment is not included in the model - it will be added in a future version.

A distributed-delay model was used to predict population growth of red flour beetle as a function of inside air temperature. The model uses a distributed delay to simulate variation in developmental time, manage survivorship, and move insects through stages. The model predicts mean insect density for each floor of the mill based on historical hourly inside air temperature for each floor (we may add relative humidity to the model if studies show this to be an important variable). The model consists of four parts: 1) an equation for rate of insect development as a function of temperature and RH; 2) a delay process for moving insects through stages; 3) an equation for age-specific fecundity as a function of temperature; 4) stage-specific mortality for methyl bromide or sulfuryl fluoride fumigation (stage-specific mortality for heat-treatment will be added in a later version of the model). Starting numbers are entered for each insect stage and for each floor of the mill. The date of each fumigation, type of fumigant used (methyl bromide or sulfuryl fluoride), and the percent of the population that will not be exposed to the fumigant can be specified (refugia). Validation data was obtained by monitoring a flour mill from 2002 to 2004 (Campbell et al., 2010ab). Pheromone/food-oil baited pitfall traps were placed throughout the building with eleven traps on each floor. The traps were inspected and replaced every 2 weeks (pheromones were replaced every 6 weeks). Hobo temperature recorders were placed at one location on each floor.

Trap catch field data (2002-2003) showed that the two methyl bromide fumigations knocked down the red flour beetle population (Fig. 1). The simulated numbers of adult red flour beetle tended to follow trap catch fairly well. Both the actual population and the simulated red flour beetle numbers increased rapidly in August following the first fumigation. The rapid increase was probably due to warmer temperatures. Population growth following the second fumigation was slower; this was probably due to lower temperatures inside the building during the fall and winter. Figure 2 shows trap catch data (2003-2004) for the same flour mill, but fumigated with sulfuryl fluoride on 19 June 2004. Both the simulated number of red flour beetle and the actual trap catch increased relatively slowly from September until April. The sulfuryl fluoride fumigation in June reduced the population; however the population quickly rebounded a few weeks later. The warmer air temperatures in June may have contributed to the rapid increase in adult numbers following fumigation. We plan to conduct additional validation studies with the model in other flour mills. Future enhancements to the model will include the ability to simulate facility heat treatments and fogging with aerosols. The model should be a valuable tool that can be used to develop optimal IPM strategies for the red flour beetle in flour mills.

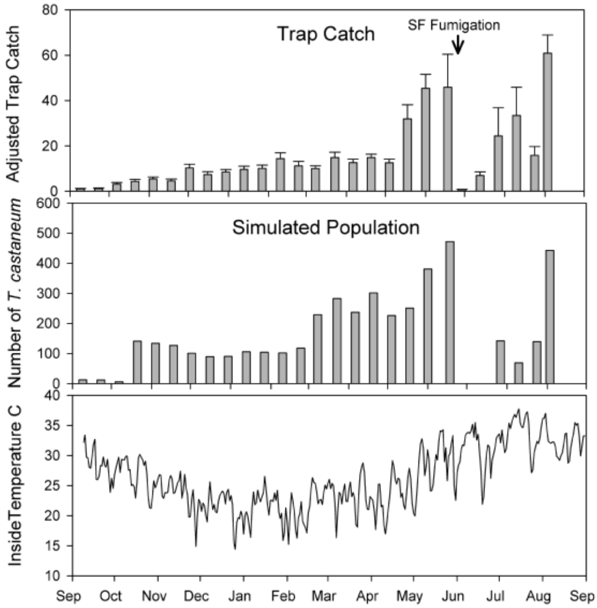

Figure 1 Mean red flour beetle trap catch (2-week duration), model predicted insect numbers and hourly inside building temperatures for a flour mill located in central Kansas USA. The flour mill was fumigated with methyl bromide (20 g for 24 h) on 28 June 2002 and 23 August 2002.

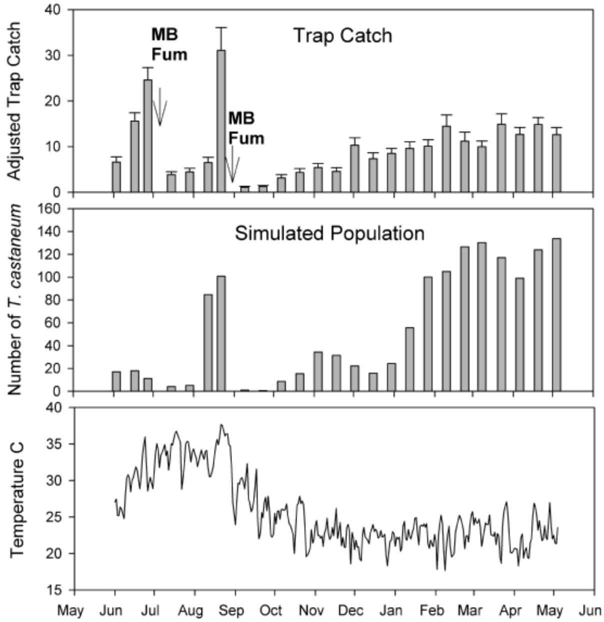

Figure 2 Mean red flour beetle trap catch (2-week duration), model predicted insect numbers and hourly inside building temperatures for a flour mill located in central Kansas USA. The flour mill was fumigated with sulfuryl fluoride (111 g for 18 h) on 19 June 2004.

❖ This abstract reports the results of research only. Mention of a proprietary product or trade name does not constitute a recommendation or endorsement by the US Department of Agriculture or Kansas State University.

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