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Supercooling point variability in the Indian meal moth, *Plodia interpunctella* (Hübner) (Lepidoptera: Pyralidae)

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Abstract

Factors affecting the supercooling point (SCP) of the Indian meal moth, *Plodia interpunctella* (Hübner), were investigated under various conditions. The effects of geographic origin, time under laboratory conditions, laboratory diet, stage of development, age within stage, and season on *P. interpunctella* SCP were examined. Overall, SCPs ranged from -28.6 to -2.4 °C. At the times of collection, differences in SCP between field-collected individuals and individuals from laboratory sources were negligible. The minimum observed SCP for most of the cultures tested soon after collection was below -20 °C. After 7 months under laboratory conditions, the mean SCP of field-collected and laboratory-reared cultures remained unchanged. No particular trend in SCP was observed when comparing cultures from northern and southern regions. Differences in laboratory diets did not affect mean SCP. Mean SCP for 1- and 4-d-old eggs was similar. Eggs (-24.4 °C), first instars (-23.5 °C), pupae (-22.2 °C), and adults (-22.4 °C) had lower mean SCPs than later instar larvae (-14.4 to -11.6 °C). When confined in the laboratory for 8 months under conditions which were not controlled, monthly mean SCP for the same culture varied by as much as 5.7 °C. *Plodia interpunctella* appeared to regulate its SCP as the season changed, with a relatively high mean SCP during summer and a marked decline of more than 10 °C in fall. The SCPs obtained in this study suggest that very low temperatures may be needed for disinfestation of *P. interpunctella* at all stages of development.

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Keywords: Indian meal moth; *Plodia interpunctella*; Cold hardiness; Supercooling point; Low temperature

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1. Introduction

The Indian meal moth, *Plodia interpunctella* (Hübner), is a pest that attacks many stored commodities around the world (Tzanakakis, 1959; Na and Ryoo, 2000) and it has been identified as one of the most cold-hardy stored-product insects (Fields, 1992). In addition, *P. interpunctella* has been classified as a freeze-intolerant insect (Lee et al., 1992).

The supercooling point (SCP) signifies the temperature at which spontaneous freezing occurs (Zachariassen, 1985). It is one of many indicators used to compare the relative cold hardiness of related freeze-intolerant species or of stages within a species (Salt, 1953; Bale, 1987; Chauvin and Vannier, 1997). The ability to supercool, defined as depressing the freezing points of body fluids to levels where crystallization is avoided, is often used synonymously with cold hardiness. However, the ecological significance of the SCP as a measure of cold hardiness remains unclear for numerous species because high pre-freeze mortality can occur as a result of chill injury (Lee and Denlinger, 1985). Bale (1996) presented many examples for freeze-intolerant species in which the SCP was not a reliable indicator of cold hardiness, together with reasons why subcategories should be used to classify organism survival below 0 °C. Despite the controversy about the validity of the SCP as a measure of insect cold hardiness, the SCP is still considered the absolute lower lethal temperature for many freeze-intolerant species (e.g., Renault et al., 2002) and may be used as a target temperature for rapid disinfestation of those species (Chauvin and Vannier, 1997).

Supercooling points in *P. interpunctella* vary widely in the literature from –10.3 °C in unacclimated larvae (Lee et al., 1992) to –22.0 °C in cold acclimated, laboratory-reared larvae (Naemullah et al., 1999). Supercooling points of –10 °C in a freeze-intolerant insect could not confer a high degree of protection in low-temperature environments, such as grain storage facilities in northern tier states. We set out to investigate this discrepancy by examining the extent of SCP variability in *P. interpunctella* under different conditions. A better understanding of the ability of *P. interpunctella* to avoid freezing may have potential for use in control of this pest with low temperatures.

2. Materials and methods

2.1. Insects and rearing conditions

Plodia interpunctella larvae or adults were obtained from field and laboratory sources. A total of 10 cultures were obtained from different geographical locations. Field-collected individuals were obtained from three sites in Minnesota, one in Texas, and one in Oklahoma. Laboratory-reared individuals were provided by five research laboratories in the US. Individuals from laboratory cultures had been held at similar rearing conditions but fed different diets. After collection, cultures were kept at 28 °C, 65–70% r.h., and a 14:10 (L: D) h cycle. Insects were fed a diet composed of wheat bran, chick feed, corn meal, glycerol, honey, and water at a volumetric ratio of 30:20:10:6.5:1.5:1.

2.2. SCP determination

Supercooling points were measured using surface contact thermometry (Carrillo et al., 2004). Individual *P. interpunctella* at different stages (excluding eggs) were immobilized in a 95 × 15 mm

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