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A wild strain of *Plodia interpunctella* (Hübner) (Lepidoptera: Pyralidae) from farm-stored maize in South Carolina: Development under different temperature, moisture, and dietary conditions ☆

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Abstract

The purpose of this study was to determine the duration of immature development and survivorship of *Plodia interpunctella* (Hübner) on maize over a range of temperatures and grain moisture contents encountered in maize stored on farms in the southeastern states (USA). Laboratory cultures were established with moths collected from farm-stored maize in South Carolina and maintained on cracked maize at 30 °C and 60% r.h. The incubation period and percentage hatch of eggs was determined at 18 combinations of temperature and r.h. Hatch was <1% at 15 and 40 °C. In the range 20–35 °C, percentage hatch declined as temperature increased, and the mean incubation period ranged from 3.1 to 8.5 d. Neither percentage hatch nor incubation period were affected by r.h. between 43% and 76%. The relationship between mean developmental period (oviposition to adult eclosion) and temperature was well described by a quadratic polynomial that predicted a decline from 67.6 to 30.1 d as temperature increased from 20 to 31.1 °C, followed by an increase to 38.5 d as temperature increased further to 35 °C. The results suggest a lower temperature threshold for development near 15 °C and an upper limit slightly greater than 35 °C. Moisture content had a significant effect on developmental period at all the temperatures studied, but the pattern of variation with moisture depended upon the temperature.

Keywords: Stored-product insects; *Plodia interpunctella*; Development; Survival; Stored maize

1. Introduction

Plodia interpunctella is a major cosmopolitan pest of granaries, food processing plants, warehouses, retail stores, and households; and the larvae are able to feed on a wide range of dried vegetable and animal materials including grain, cereal products, oilseeds, dried fruits, dried vegetables, nuts, and animal feed (Richards and Thomson, 1932; Cox and Bell, 1991). Although the effects of host commodity, temperature, and moisture on rate of development and survivorship of the immature stages are well documented (Prevett, 1971; Bell, 1975; Mbata and Osuji, 1983; Allotey and Goswami, 1990; Mbata, 1990; Johnson et al., 1992, 1995; Locatelli and Biglia, 1995; Locatelli and Limonta, 1998; Na and Ryoo, 2000; Perez-Mendoza and Aguilera-Peña, 2004), quantitative data sets sufficient for the development and validation of computer simulation models are lacking.

The purpose of the study reported here was to determine the duration of immature development and survivorship of *Plodia interpunctella* (Hübner) on maize over the range of temperature and moisture content encountered in maize stored on farms in the southeastern states of the United States of America. It was undertaken in concert with field studies of farm-stored maize in South Carolina (Arbogast and Throne, 1997; Arbogast and Chini, 2005) to provide quantitative data required for modeling the population

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dynamics of this moth and optimizing control strategies (Throne,1995).

2. Materials and methods

2.1. Temperature and humidity control

Constant temperatures of 15, 20, 25, 30, 35, and 40 ± 0.5 °C were maintained in six separate environmental rooms (Environmental Growth Chambers, Chagrin Falls, OH), each held at a constant relative humidity (r.h.) of 60 ± 5%. Constant relative humidities were maintained in clear polystyrene boxes (23 × 31 × 10 cm) (Tri-State Plastics, Latonia, Kentucky) by means of saturated salt solutions (Table 1) (Greenspan, 1977) prepared with reagent grade salts and distilled water. The water was brought to a boil on a stirring hot plate, the heat was turned off, and salt was added with continuous stirring until saturation was achieved. The saturated solutions were stored over salt in stoppered flasks at room temperature for 2–3 wk before use. They were then stirred thoroughly and poured over dry salt in the boxes to form a shallow slurry. Each box was provided with a latticed false floor with 13 × 13 mm openings (polystyrene eggcrate, Select Acoustic Supply, Concord, Ont.) to support insect cages and containers with maize samples. A mat of the same material was placed on the floor of each box to prevent splashing of the solutions.

Table 1
Equilibrium relative humidity over saturated salt solutions at various constant temperatures and equilibrium moisture content of the maize hybrid Pioneer 3320 held over these solutions

Salt	Temp. (°C)	Equilibrium r.h. (%)[a]	Equilibrium m.c. (%)	
			N	Mean ± SE[b]
K_2CO_3	15	43.2	—	—
	20	43.2	14	11.7 ± 0.05
	25	43.2	12	11.0 ± 0.03
	30	43.2	14	10.7 ± 0.04
	35	—	12	11.3 ± 0.13
	40	—	—	—
NaBr	15	60.7	—	—
	20	59.4	14	13.4 ± 0.04
	25	57.6	14	12.7 ± 0.02
	30	56.0	14	12.5 ± 0.03
	35	54.6	14	11.7 ± 0.03
	40	53.2	—	—
NaCl	15	75.6	—	—
	20	75.5	12	14.8 ± 0.06
	25	75.3	12	14.8 ± 0.04
	30	75.1	12	14.7 ± 0.03
	35	74.9	12	14.3 ± 0.04
	40	74.7	—	—

All maize samples reached moisture equilibrium in 49 d or less, and the means include all measurements made on the 49th day or later.
[a] Greenspan (1977).
[b] Equilibrium moisture content was not determined at 15 and 40 °C.

2.2. Maize

Pioneer 3320, a maize hybrid commonly grown in the southeastern United States, was used for rearing stock cultures and in all experiments. The equilibrium moisture content of this hybrid at various combinations of temperature and r.h. (Table 1) was determined by holding samples at constant temperatures over saturated salt solutions in constant humidity boxes and measuring the moisture content at intervals of 2–4 d with a Motomco Automatic Grain Moisture Tester Model 919 (DICKEY-john® Corp., Auburn, IL). Two samples in separate boxes were used for each temperature–humidity combination. Moisture determinations were plotted against time and were continued until the graph indicated clearly that the grain had reached equilibrium, which occurred in 49 d or less in all combinations. Measurements were continued for up to 65 d, and all readings at 49 d or more were pooled to calculate the mean (± SE) equilibrium moisture content at each combination.

2.3. Moth cultures

Cultures of *P. interpunctella*, established with moths collected from farm-stored maize in South Carolina, were reared on cracked maize at 30 ± 0.5 °C and 60 ± 5% r.h. in an environmental chamber. Each culture was contained in a 0.95-l jar covered with filter paper held in place by a lid with two holes (3 cm in diam.) for ventilation. Eggs were collected by confining recently emerged adults in a 0.95-l jar containing a piece of pleated black construction paper (to provide resting sites) and covered by a lid with 18-mesh wire screen. The jar was placed in a darkened box and eggs were collected after various periods of time by shaking them onto black construction paper. The collected eggs were surface-sterilized as necessary with 1% formalin to control granulosis virus before using them to set up new cultures. Fresh rearing stock was collected periodically from the storage bins to ensure that no moths were cultured for more than 12 generations.

2.4. Egg development

The incubation period and percentage hatch of eggs were determined at 18 combinations of constant temperature and relative humidity (Table 1). The cages used to study egg development consisted of clear acrylic blocks (22 × 12.5 × 1.2 cm) with fifty 0.96-cm holes bored through them. The bottoms of the holes were covered by a piece of fine-mesh nylon screen (mesh opening of 64 μ; Nitex, Sefar America, Depew, NY) glued to the underside of the block, and the whole block was supported on feet about 1 cm high. One egg was placed in each hole, which was then stoppered with a No. 2 cork. Observations were made daily