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TEMPERATURE DEPENDENCE OF BOLL WEEVIL, *ANTHONOMUS GRANDIS*, HOST-FREE SURVIVAL

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Abstract

Most studies of boll weevil overwinter survival have focused on the effects of severe winter temperatures. Consequently, little is known regarding the temperature dependence of such survival in locales where sub-freezing temperatures infrequently occur. The temperature dependence of host-free survival of diapausing weevils was examined at four constant temperatures ranging from 12.8 to 29.4ºC. No differences in survival were detected between weevil sexes. Significant influences of temperature on survival were observed, but these relationships changed over the course of the survival period. Survival was consistently lowest at 29.4ºC. Survival rates at 12.8 and 18.3ºC were initially higher than those at 23.9ºC, but after the 20th week survival at 12.8 and 23.9ºC were similar. From week 21 until week 40, when the numbers of live weevils remaining were low for all temperatures, survival at 18.3ºC remained higher than survival at other temperatures. The lower-than-expected survival at 12.8ºC suggests the occurrence of a chronic low-temperature injury not previously recognized. These results provide additional insight into the dynamics of boll weevil overwintering and should be useful in developing models to predict weevil survival in areas where sub-freezing temperatures seldom occur.

Introduction

Adequate understanding of the dynamics of boll weevil, *Anthonomus grandis* Boheman, overwinter survival is essential for development of optimal management and suppression strategies. Although the diapause phenomenon has been extensively studied, influences of environmental factors on overwinter survival have received little attention except for the effects of freezing temperatures (e.g., Bondy and Rainwater 1942, Gaines 1953, Carroll et al. 1993, Parajulee et al. 1996). Thus, most studies have concentrated on the association of low weevil survival with severe winter temperatures. However, many areas of the southern Cotton Belt infrequently experience sub-freezing temperatures. Further, recent studies of boll weevil supercooling points (C. P.-C. Suh and D. Spurgeon, unpublished data) imply that much observed winter mortality may not be a direct result of weevils freezing. A better understanding of the impacts of ambient temperatures on the longevity of overwintering boll weevils would be useful to ecological studies of survival and spring emergence patterns, and in assessing the potential usefulness of cultural practices that manipulate the duration of the cotton-free period. This information could also improve the timing of region-specific diapause treatments if weevil survival rates could be reliably related to winter temperature patterns. Such a relationship would allow prediction of dates after which overwintered weevils could be expected to survive to the following cropping season. The objective of the research was to evaluate the temperature-dependence of host-free survival of diapausing boll weevils.

Materials and Methods

Boll weevil adults were reared from infested squares collected from cotton plants. Infested squares were held in 20 X 20 X 20-cm screened plexi-glass cages in an environmental chamber at 29.4±1°C with a photoperiod of 13:11 [L:D] h. Beginning 5 or 6 d after squares were collected, pupae were removed from the squares and placed in 100 X 15-mm petri plates containing a thin layer of moistened vermiculite. Squares containing larvae were returned to the cage and were reexamined for pupae on subsequent days. Plates of pupae were returned to the environmental chamber and examined for adults twice daily. Newly eclosed adults were sexed using the method of Sappington and Spurgeon (2000) and were assigned to feeding cartons on the day of eclosion.

Diapausing weevils were obtained by providing a boll diet similar to that used by Spurgeon and Esquivel (2000). Single-sex groups of 40 weevils were held in 473-ml cardboard cartons closed with screened lids. Each group was fed 4 small bolls (17 – 25 mm diameter, mostly 20 – 25 mm) thrice weekly, and was supplied water in a 29.5-ml plastic cup with a cotton wick extending through the lid. A total of 28 cartons of weevils (14 cartons of each sex) were maintained at 29.4±1°C under a 13:11 [L:D] h photoperiod during the feeding period. After feeding for 14 d a survival cohort of 22 – 25 randomly selected weevils was removed from each carton. Each weevil was marked on the right elytron with non-toxic paint (Speedball Painters, Hunt Manufacturing, Statesville, NC) to identify sex (white, male; pink, female). Remaining weevils in each carton (≥8) were dissected to determine the proportion of diapause. Females with hypertrophied fat bodies and undeveloped ovaries containing no or only pre-vitellogenic oocytes, and males with hypertrophied fat bodies and atrophied testes opaque with fat, were considered in diapause as described by Spurgeon and Raulston (1998). Two survival cohorts, one of males and one of females eclosed on the same date, were combined and held in each of 14 20 X 20 X 20-cm screened plexi-glass cages. Each cage contained a crumpled craft-paper refuge (30 X 45 cm) and a water cup equipped with a cotton wick. Cages were distributed among four environmental chambers each set at a different temperature (12.8, 18.3, 23.9, and 29.4±1ºC; 55, 65, 75, and 85±2°F). Four cages of weevils were assigned to each the 12.8 and 23.9°C chambers, and three cages were assigned to each of the 18.3 and 29.4°C chambers. Mortality was recorded weekly.

To ensure that differences in diapause status among cohorts assigned to temperature treatments were not responsible for observed differences in weevil longevity, the proportion of diapausing weevils was compared among temperature treatments by ANOVA using the SAS procedure PROC GLM (SAS Institute 1998). The ANOVA model contained terms for temperature, sex, and their interaction. Proportions were arcsine square root transformed before analysis (Zar 1984).

Effects of temperature and sex on weevil survival were examined by repeated-measures analysis using the REPEATED statement of the SAS procedure PROC GLM (SAS Institute 1998). The ANOVA model contained terms for temperature, sex, week, and their interactions. Because degrees of freedom were insufficient to permit a test of sphericity or multivariate analyses of the repeated effects, statistical significance of model terms containing the repeated factor (week) were assessed based on the Greenhouse-Geisser adjusted P (*G-G Adjusted P*). Differences in survival among the temperature treatments for each week were examined using the REGWQ option of the MEANS statement of PROC GLM (SAS Institute 1998).

Results and Discussion

Analyses indicated that the proportion of diapause was similar among cohorts assigned to different temperature treatments ($F = 0.35$; df = 7, 20; $P = 0.92$). The proportion of weevils in diapause was 0.78 for females and 0.85 for males, and ranged from 0.79 for the 12.8ºC treatment to 0.85 for the 18.3ºC treatment.

The respective effects of sex and the temperature by sex interaction were not statistically significant (sex, $F = 1.13$; df = 1, 20; $P = 0.30$; temperature by sex, $F = 0.64$; df = 3, 20; $P = 0.60$). Thus, survival rates of male and female weevils were roughly similar irrespective of temperature. Likewise, the week by sex ($F = 1.06$; df = 55, 1100; $P = 0.36$) and week by temperature by sex ($F = 0.66$; df = 165, 1100; $P = 1.00$) interactions failed to indicate differences in survival patterns of male and female weevils.

Significant temperature ($F = 19.96$; df = 3, 20; $P < 0.01$) and week ($F = 428.72$; df = 55, 1100; *G-G Adjusted P* <0.01) effects were indicated by the analysis. Further, the week by temperature interaction ($F = 10.14$; df = 165, 1100; *G-G Adjusted P* <0.01) indicated that the effects of temperature were not consistent throughout the entire survival period. Examination of the respective survival curves (Fig. 1) revealed several notable trends. First, weevil survival at 23.9º was statistically similar to that at 29.4ºC, and survival at 12.8º was similar to that at 18.3ºC, for the initial four weeks of the host-free period. By the sixth week survival at 29.4ºC was significantly less than at other temperatures, which were similar to each other in survival rate until the 21st week. Beginning at the 21st week and until week 40, the survival rate was highest at 18.3ºC. From the 21st week until the end of the survival period weevil survival rates at 12.8 and 23.9ºC remained similar.

Differences in weevil survival rates among temperatures were expected, but the level of complexity of this relationship indicated by the week by temperature interaction was unanticipated. Changes in the relationships between temperature and survival that occurred near the fourth week of the host-free period can be explained by the presence of a small proportion of reproductive weevils in each cohort. For the highest two temperatures this 4-wk period roughly corresponds to the time required for reproductive weevils to die (unpublished data). However, survival trends observed at 12.8ºC, relative to those at other temperatures, are not as easily explained. It is unlikely that these trends were anomalous because similar trends were observed in earlier experiments (unpublished data). It seems more likely that the reduced survival at this lowest temperature is a product of chronic low-temperature injury to internal tissues. These results are particularly meaningful to southern areas of the U.S. Cotton Belt, and to other areas in years with mild winters, because they provide an explanation for environmentally-induced weevil mortality apart from sub-freezing temperatures. Although the mechanisms responsible for this mortality have not been examined, these results illustrate previously unreported complexities inherent to the relationship between temperature and boll weevil host-free survival. Additional efforts to model these relationships should provide a tool for predicting survival rates and timing associated management practices in areas of the U.S. Cotton Belt that remain infested by the boll weevil.

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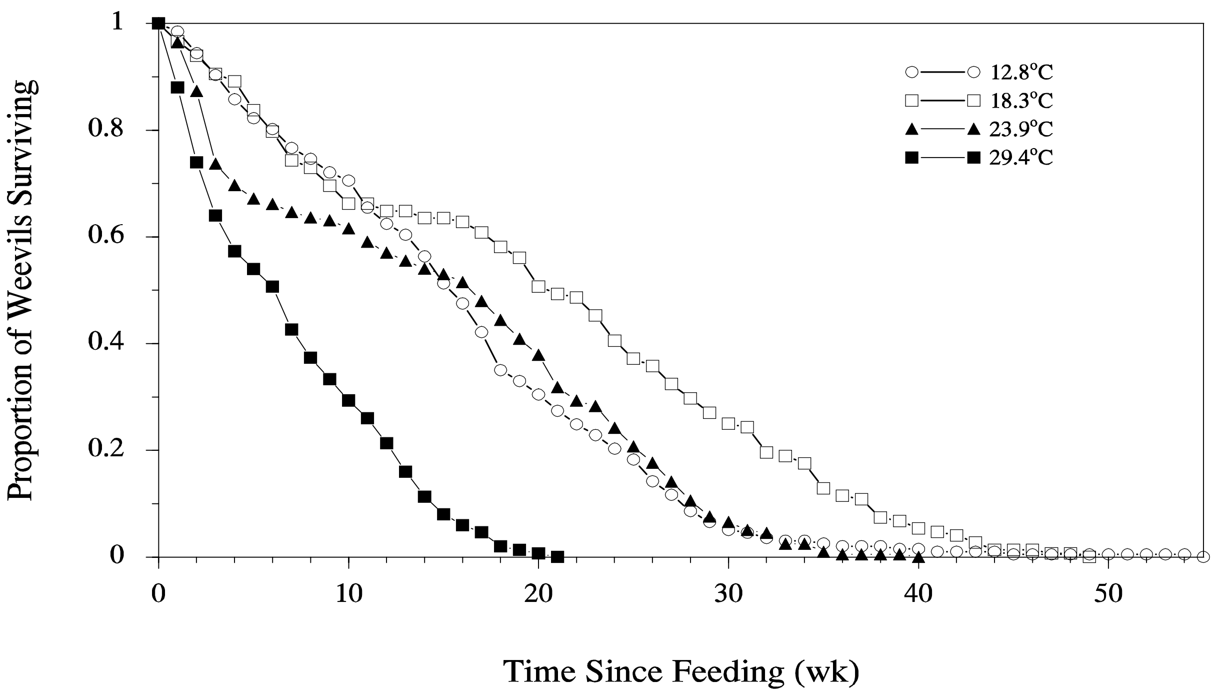

Figure 1. Host-free survival rates of diapausing boll weevils at four constant temperatures.