INSULATING ABILITIES OF SIX BOLL WEEVIL OVERWINTERING HABITATS FROM THE ROLLING PLAINS OF TEXAS

M. N. Parajulee, L. T. Wilson and P. J. Trichilo
Department of Entomology
Texas A&M University
College Station, TX
D. R. Rummel and S. C. Carroll
Texas Agricultural Research and Extension Center
Lubbock, TX
J. E. Slosser
Texas Agricultural Research and Extension Center
Vernon, TX
T. W. Fuchs
Texas Agricultural Research and Extension Center
San Angelo, TX

Abstract

Temperature data are unavailable for most boll weevil overwintering habitats. As a result, ambient data often are used to estimate overwintering survival and emergence. In this study, relationship of ambient and overwintering habitat temperatures was determined for six habitats in the Rolling Plains of Texas. The amplitude of the daily temperature cycle in the leaf litter of each habitat was dampened compared with that recorded for ambient, with the average minimum daily leaf litter temperatures 3 to 6° C higher and the average maximum daily leaf litter temperatures 4 to 6°C lower than the average ambient temperatures. Multiple regressions of hourly and daily min-max leaf litter temperatures explained 93% of the variability, with ambient temperature and week of year being significant variables in all regressions. Except in mesquite-grass pasture, ambient temperatures overestimated positive degree-days (>6.1°C) experienced by overwintering weevils by 6-16%. All habitats had significantly fewer cumulative negative degree-days (<0.0°C) compared with that calculated for ambient.

Introduction

In the Rolling Plains of Texas, the adult boll weevil, *Anthonomus grandis grandis* Boheman, initiates diapause in early August (Sterling and Adkisson 1974), with the spring-summer emergence from diapause continuing in some cases to mid-August the following year (Carroll and Rummel 1985, Slosser and Fuchs 1991). The proportion of diapausing weevils that successfully overwinter is largely dependent on time of entry into overwintering habitats (Fenton and Dunnam 1927, Rummel and Carroll 1983, Parajulee et al. 1996), winter severity as reflected by low temperatures and rainfall (Price et al. 1985, Stone et al. 1990, Parajulee et al. 1996), and the insulating capacity of overwintering habitats (Bottrell et al. 1972, Slosser et al. 1984, Carroll et al. 1993).

The primary boll weevil overwintering habitats in the Texas High Plains and Rolling Plains include shinnery oaks, *Quercus* spp., mesquite, *Prosopis glandulosa* Torrey, pecan, *Carya illinoensis* (Wagenheim) Koch, shelterbelt plantings, and weeping lovegrass, *Eragrostis curvula* (Schrader) Nees von Esenbeck (Bottrell et al. 1972, Slosser and Fuchs 1991, Carroll et al. 1993). The tall shinnery oak, pecan, and shelterbelt plantings produce leaf litter 5-10 cm deep; low shinnery brush produces litter half as deep as that of tall shinnery motte, and mesquite, which is mostly covered by native grasses in this region, produces litter 1/4 as deep as that of tall shinnery motte (Slosser and Fuchs 1991, Slosser 1993). The weeping lovegrass is a bunch-type grass that produces a large amount of plant residue suitable for overwintering weevils (Brown and Phillips 1989). Because of differences in leaf litter depth and canopy cover, the temperatures experienced by weevils in each habitat may vary, hence weevil survival and their pattern of emergence may be quite different among the overwintering habitats (Rummel and Adkisson 1970, Carroll et al. 1993). Because ambient temperature data are much more readily available than are leaf litter temperature data, ambient data often are used to predict the phenology of overwintering weevils (Gaines 1943, Curry et al. 1980, Leggett et al. 1988, Stone et al. 1990). The objective of this study was to establish the relationship between ambient and overwintering habitat temperatures in the Rolling Plains of Texas for greater accuracy in evaluating boll weevil overwintering survival and spring emergence.

Materials and Methods

Data loggers (CR-21 Micrologger, Campbell Scientific, Logan, UT) were used to monitor hourly temperatures in six boll weevil overwintering habitats from the Rolling Plains of Texas throughout the year. The habitats studied included the tall growth shinnery oak (1992-95), low growth shinnery oak (1992-95), mesquite-grass pasture (1992-95), pecan (1985-88), shelterbelt (1989-92), and weeping lovegrass (1988-89). Leaf litter temperatures (°C) were recorded at the soil surface-leaf litter interface, while the hourly ambient temperatures were recorded at 2 m above the leaf litter surface for each habitat. Temperature data were analyzed to quantify the relationship between leaf litter and ambient daily minimum-maximum and hourly temperatures for the six overwintering habitats, and to quantify the effects of fall-winter severity on the bias associated with using ambient temperature data to estimate negative and positive degree-days experienced by overwintering boll weevils.

A multiple stepwise (backward) nonlinear regression analysis (JMP, SAS Institute 1995) was performed on the hourly temperature data for each of the six habitats, with ambient temperature, hour, and week of year used as

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 2:955-959 (1997)
National Cotton Council, Memphis TN

independent variables. Similar regressions were performed on the daily minimum and maximum temperatures, with ambient temperature and week used as independent variables. Using the regression coefficients derived for each habitat, and an independent ambient temperature data set obtained from Stonewall County, positive (>6.1°C) and negative (<0.0°C) degree-days were calculated for each habitat for the diapausing period (1 September to 31 July). The independent temperature data represented two years with mild (1986-87 and 1991-92) and two with severe fall-winters (1987-88 and 1989-90).

An asymmetrical double-sine method was used to estimate positive and negative degree-days (Parajulee et al. 1997). Positive and negative degree-days also were calculated using the trapezoidal approximation method for each hourly interval and then summing the values for each day. Positive degree-days were compared using a factorial analysis of variance (ANOVA), with temperature source, winter severity (mild vs. cold winters), frequency of temperature data (hourly vs. daily), week of year, and their interactions as the sources of variability. Negative degree-days were compared as described for the positive degree-days. The significance of all statistical tests was evaluated at the 0.05 level.

Results and Discussion

The amplitude of the daily temperature cycle in the leaf litter of each of the six habitats was dampened compared with that recorded for the ambient. The average minimum daily leaf litter temperature was 3.2°C higher in the shelterbelt habitat, followed by mesquite-grass pasture (3.5°C), tall shinnery motte (3.6°C), low shinnery brush (3.8°C), lovegrass (4.0°C), and pecan (6.0°C). Likewise, the average maximum daily leaf litter temperature was 3.8°C lower in shelterbelt, followed by pecan (3.9°C), lovegrass (3.9°C), mesquite-grass pasture (4.1°C), low shinnery brush (5.5°C), and tall shinnery motte (6.1°C). Multiple regression analyses of hourly leaf litter temperatures explained an average of 93% of the variability in the data, with significant hourly ambient temperature, week, and (week)2 effects (Table 1). The same terms in addition to an ambient x week interaction term explained an average of 96 and 90% of the variability, respectively, when estimating daily leaf litter minimum and maximum temperatures (Table 2).

Both positive and negative degree-days were significantly affected by temperature source, winter severity, and week, whereas sampling frequency significantly affected positive degree-days only. Mesquite-grass pasture accumulated the most positive degree-days, followed by pecan, low shinnery brush, lovegrass, tall shinnery motte, and shelterbelt, with all but the positive degree-days of mesquite-grass pasture being significantly less than ambient (Table 3). Mesquite-grass pasture produces the least amount of leaf litter of the habitats examined, except weeping lovegrass (Slosser and Fuchs 1991, Carroll et al. 1993), and has a canopy that is mostly open, unlike other habitats which are either covered by a tree canopy or by the bunch-type thicket as with lovegrass. As a result, the mesquite-grass pasture habitat receives greater exposure to solar radiation during daylight hours (Slosser and Fuchs 1991). The shelterbelt habitat accumulated the lowest number of positive degree-days because of the dense canopy of thickly planted trees of the different species. In addition, this habitat produces leaf litter as deep as that produced by pecan and tall shinnery motte (Slosser 1993). More positive degree-days was believed coincidental with the years of severe winter rather than a cause-and-effect relationship (Table 3). Frequency of temperature data significantly affected the estimated positive degree-days, with the daily min-max data overestimating the cumulative positive degree-days by 2.5% compared with that based on hourly data.

Fewer total negative degree-days accumulated in all habitats compared with that calculated for ambient (Table 4). In pecan, 99% fewer total negative degree-days accumulated, followed by shelterbelt (95%), tall shinnery motte (88%), low shinnery brush (82%), lovegrass (71%), and mesquite-grass pasture (50%). Winter severity greatly affected the insulating capacities of the overwintering habitats. During years with mild winters, lovegrass, low shinnery brush, and tall shinnery motte were not significantly different from each other in their insulating capacity. Similarly, tall shinnery motte, low shinnery brush, shelterbelt, and pecan were not significantly different from each other during the years with mild winters (Table 4). In contrast, although the ranking of the habitats in their negative degree-day accumulation did not change, years with severe winters discriminated the insulating capacity of overwintering habitats to a greater degree. The greater insulating capacity of pecan, shelterbelt, and tall shinnery motte habitats can be attributed to the amount of leaf litter they produce. Of the 6 habitats studied, pecan, shelterbelt, and tall shinnery motte produced leaf litter 5-10 cm deep; low shinnery brush produced litter half as deep as that of tall shinnery motte, and mesquite-grass pasture, which is mostly covered by native grasses, produced litter 1/4 as deep as that of tall shinnery motte (Slosser and Fuchs 1991, Slosser 1993).

References

Bottrell, D. G., J. R. White, D. S. Moody, and D. D. Hardee. 1972. Overwintering habitats of the boll weevil in the Rolling Plains of Texas. Environ. Entomol. 1: 633-638.

Brown, C. M., and S. A. Phillips. 1989. Weeping lovegrass as an overwintering habitat for the boll weevil (Coleoptera: Curculionidae). J. Econ. Entomol. 82: 799-802.

Carroll, S. C., and D. R. Rummel. 1985. Relationship between time of boll weevil (Coleoptera: Curculionidae) emergence from winter habitat and response to grandlure-baited pheromone traps. Environ. Entomol. 14: 447-451.

Carroll, S. C., D. R. Rummel, and E. Segarra. 1993. Overwintering by the boll weevil (Coleoptera: Curculionidae) in conservation reserve program grasses on the Texas High Plains. J. Econ. Entomol. 86: 382-393.

Curry, G. L., P.J.H. Sharpe, D. W. DeMichele, and J. R. Cate. 1980. Towards a management model of the cotton boll weevil ecosystem. J. Environ. Manage. 11: 187-223.

Fenton, F. A., and E. W. Dunnam. 1927. Winter survival of the cotton boll weevil at Florence, S. C. J. Econ. Entomol. 20: 327-336.

Gaines, R. C. 1943. Relation between winter temperatures, boll weevil survival, summer rainfall, and cotton yields. J. Econ. Entomol. 36: 82-84.

Leggett, J. E., W. A. Dickerson, K. P. Burnham, S. H. Roach, A. R. Hopkins, and F. R. Planer. 1988. Boll weevil (Coleoptera: Curculionidae): emergence profile of overwintered weevils measured by grandlure-baited traps and predicting total emergence. Environ. Entomol. 17: 903-910.

Parajulee, M. N., L. T. Wilson, D. R. Rummel, S. C. Carroll, and P. J. Trichilo. 1996. Climatic data-based analysis of boll weevil (Coleoptera: Curculionidae) overwintering survival and spring emergence. Environ. Entomol. 25: 882-894.

Parajulee, M. N., L. T. Wilson, D. R. Rummel, S. C. Carroll, P. J. Trichilo, J. E. Slosser, and T. W. Fuchs. 1997. Relationship between ambient and leaf litter temperatures in overwintering habitats of boll weevil. Environ. Entomol. (in press).

Price, J. R., J. E. Slosser, and G. J. Puterka. 1985. Factors affecting survival of boll weevils in winter habitat in the Texas Rolling Plains. Southwest. Entomol. 10: 1-6.

Rummel, D. R., and P. L. Adkisson. 1970. Distribution of boll weevil-infested cotton fields in relation to overwintering habitats in the High and Rolling Plains of Texas. J. Econ. Entomol. 63: 1906-1909.

Rummel, D. R., and S. C. Carroll. 1983. Winter survival and effective emergence of boll weevil cohorts entering winter habitat at different times. Southwest. Entomol. 8: 101-106.

SAS Institute. 1995. JMP, version 3. SAS Institute, Cary, NC.

Slosser, J. E. 1993. Effect of habitat differences on boll weevil overwintering survival and emergence, pp. 935-937. *In* Proceedings, Beltwide Cotton Conferences. National Cotton Council, Memphis, TN.

Slosser, J. E., and T. W. Fuchs. 1991. Overwinter survival of boll weevils (Coleoptera: Curculionidae) in the Texas Rolling Plains. Environ. Entomol. 20: 877-881.

Slosser, J. E., J. R. Price, and P. W. Jacoby. 1984. Effect of two shinnery oak habitats on winter survival and on spring and early summer emergence of the boll weevil. Southwest. Entomol. 9: 240-244.

Sterling, W., and P. Adkisson. 1974. Seasonal incidence of diapause and reproduction in boll weevils inhabiting the High and Rolling Plains of Texas. Tex. Agric. Exp. Stn. Misc. Publ. MP-1145.

Stone, N. D., D. R. Rummel, S. C. Carroll, M. E. Makela, and R. E. Frisbie. 1990. Simulation of boll weevil (Coleoptera: Curculionidae) spring emergence and overwintering survival in the Texas Rolling Plains. Environ. Entomol. 19: 91-98.

Table 1. Coefficients of parameters to estimate hourly leaf litter temperatures in six boll weevil overwintering habitats as a function of ambient hourly temperature and week of year.

	Boll Weevil Overwintering Habitats					
Term	TSO	LSB	MES	PEC	SLB	LGR
Intercept	-0.162	-0.666	-1.894	2.587	1.061	-1.816
Amb	0.538	0.568	0.711	0.416	0.497	0.575
Wk	0.710	0.752	0.726	0.718	0.619	0.802
Wk^2	-0.012	-0.013	-0.013	-0.012	-0.010	-0.013
R^2	0.91	0.93	0.93	0.92	0.92	0.96

TSO, Tall shinnery oak; LSB, Low shinnery brush; MES, Mesquite-grass pasture; PEC, Pecan; SLB, Shelterbelt; LGR, Lovegrass; Amb, Ambient temperature, Wk, Week of year.

Table 2. Coefficients of parameters to estimate daily minimum and maximum leaf litter temperatures in six boll weevil overwintering habitats as a function of ambient daily temperature and week of year.

	Boll Weevil Overwintering Habitats					
Term	TSO	LSB	MES	PEC	SLB	LGR
Minimum Temperature Functions						
Intercept	0.353	1.578	1.231	5.078	2.057	0.881
Amb	0.633	0.618	0.614	0.551	0.491	0.620
Wk	0.545	0.486	0.426	0.370	0.512	0.472
Amb x Wk	0.002	0.002	0.004	0.001	0.003	0.002
Wk^2	-0.008	-0.008	-0.007	-0.006	-0.008	-0.007
R^2	0.95	0.97	0.96	0.94	0.97	0.98
Maximum Temperature Functions						
Intercept	1.052	-0.553	-4.946	1.564	1.883	-1.984
Amb	0.607	0.587	0.709	0.472	0.435	0.533
Wk	0.389	0.504	1.016	0.871	0.567	0.883
Amb x Wk	-0.001	0.002	0.001	-0.003	0.002	0.001
Wk^2	-0.007	-0.010	-0.019	-0.014	-0.010	-0.016
R^2	0.83	0.88	0.90	0.88	0.94	0.94

See Table 1 for explanation of the abbreviated terms.

Table 3. Positive degree-days (> 6.1 °C) accumulated for ambient and six overwintering habitats during boll weevil overwintering months.

	Mild-winter years			Severe-winter years		
Habitat	1986	1991	Avg	1987	1989	Avg
Trapezoidal Estimation on Hourly Temperature						
Amb	3340	3401	3371a	3598	3668	3633a
TSO	3145	3177	3161c	3286	3314	3300b
LSB	3213	3247	3230bc	3366	3395	3381b
MES	3420	3464	3442a	3615	3651	3633a
PEC	3258	3289	3274b	3346	3387	3367b
SLB	2971	3005	2988d	3097	3130	3113c
LGR	3165	3200	3182c	3329	3358	3343b
Asymmetrical Double Sine Estimation on Daily Temperature						
Am	3480	3557	3519a	3722	3783	3752a
TSO	3220	3265	3243c	3355	3377	3366b
TSO	3293	3339	3316bc	3439	3462	3450b
MES	3516	3574	3545a	3706	3732	3719a
PEC	3320	3361	3340b	3403	3440	3421b
SLB	3043	3086	3064d	3163	3190	3176c
LGR	3214	3257	3236c	3368	3381	3375b

See Table 1 for explanation of the abbreviated terms. Average values within each category of winter severity followed by the same letter are not significantly different (P > 0.05, contrast for mean comparisons, SAS Institute 1995).

Table 4. Negative degree-days (< 0.0 °C) accumulated for ambient and six overwintering habitats during boll weevil overwintering months.

	Mild-winter years			Severe-winter years		
Habitat	1986	1991	Avg	1987	1989	Avg
Trapezoidal Estimation on Hourly Temperature						
Amb	45.0	39.7	42.3a	109.2	101.8	101.5a
TSO	4.8	3.4	4.1cd	14.9	11.8	13.3de
LSB	7.7	4.7	6.2cd	22.0	19.1	20.6d
MES	21.4	13.2	17.3b	60.2	54.0	57.1b
PEC	0.0	0.0	0.0d	0.0	1.8	0.9f
SLB	0.6	1.6	1.1d	5.6	7.6	6.6ef
LGR	14.9	9.1	12.0bc	36.9	24.6	30.7c
Asymmetrical Double Sine Estimation on Daily Temperature						
Amb	42.8	41.4	42.1a	112.9	97.1	105.0a
TSO	4.1	4.7	4.4cd	14.4	11.5	12.9de
LSB	6.6	6.4	6.5cd	22.0	18.2	20.1d
MES	18.9	16.0	17.4b	61.3	50.5	55.9b
PEC	0.0	0.0	0.0d	0.1	2.0	1.0f
SLB	0.7	2.0	1.3d	5.1	7.4	6.2ef
LGR	13.0	11.2	12.1bc	36.7	23.1	29.9c

See Table 1 for explanation of the abbreviated terms. Average values within each category of winter severity followed by the same letter are not significantly different (P > 0.05, contrast for mean comparisons, SAS Institute 1995).

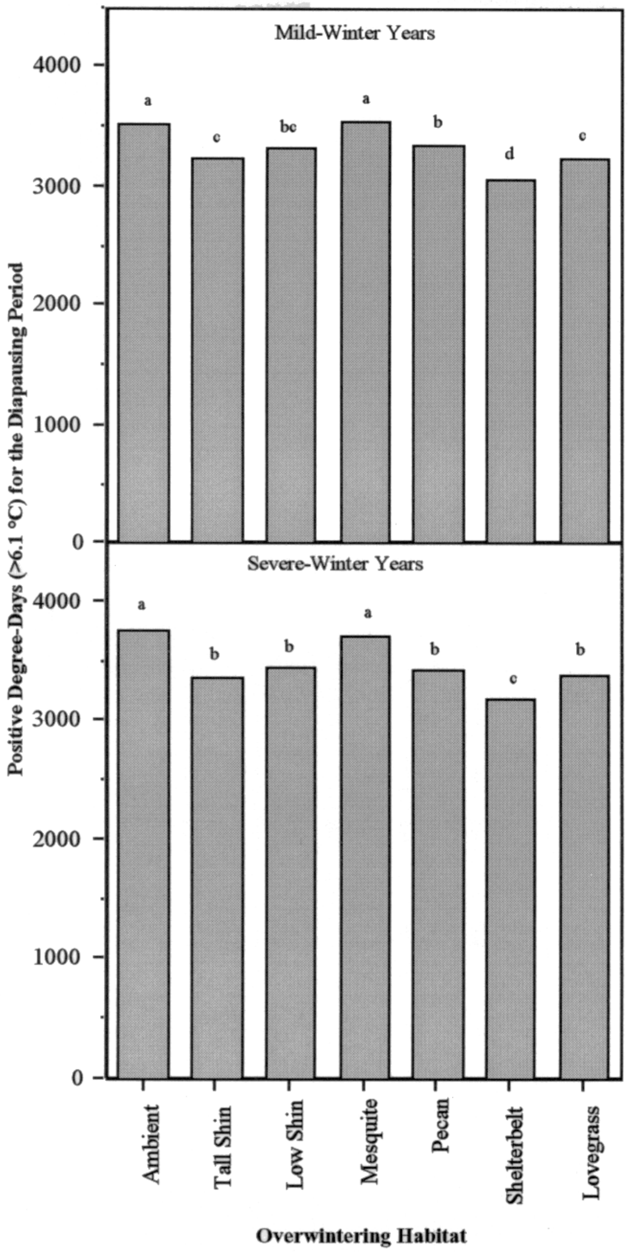

Figure 1. Positive degree-days (>6.1 °C) accumulated for ambient and six overwintering habitats during boll weevil overwintering months (September 1 to July 31).

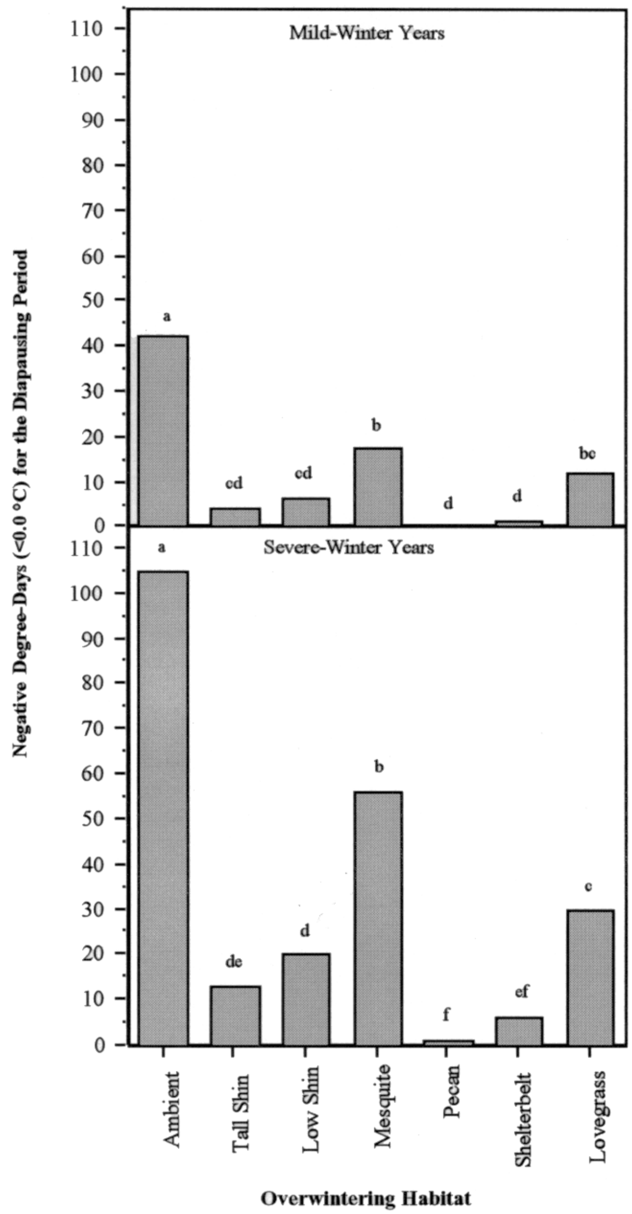

Figure 2. Negative degree-days (<0.0 °C) accumulated for ambient and six overwintering habitats during boll weevil overwintering months.