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Temperature Conditions Affecting Winter Survival of the Cigarette Beetle, *Lasioderma serricorne* (F.) (Coleoptera: Anobiidae)*

by

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SUMMARY

Winter survival of cigarette beetle larvae in three tobacco warehouses and three sheds at five locations in Japan was examined to determine critical temperature conditions for eradication under natural situations in locations where temperatures fluctuate seasonally and diurnally. In the tobacco warehouses, where mean diurnal temperature variations were less than 1 ˚C, the combined exposure to temperatures lower than 7 ˚C for 9–10 weeks and lower than 6 ˚C for 1 to 2 weeks inside tobacco cases was found to be required for eradication. Temperatures inside tobacco cases approximated the 7-day moving averages of outside temperatures but were about 1 ˚C higher. To disinfest the larvae living inside, tobacco cases should be exposed to outside temperatures lower than 6 ˚C for 7 to 8 weeks and 5 ˚C for 3 to 4 weeks. Near the critical conditions, larger diurnal temperature ranges resulted in higher winter survival rates. This result suggests that the larvae may survive even in areas cold enough to normally cause eradication provided that daytime temperatures rise sufficiently. [Beitr. Tabakforsch. Int. 22 (2006) 303–306]

ZUSAMMENFASSUNG

Das Überleben der Larven des Tabakkäfers (*Lasioderma serricorne*) im Winter wurde in drei Lagerhäusern für Tabak und drei Tabakschuppen in fünf Orten in Japan untersucht. Ziel war es, die kritischen Temperaturbedingungen für die Beseitigung des Befalls unter natürlichen Bedingungen in Gebieten mit saisonalen und tageszeitlich bedingten Temperaturschwankungen zu bestimmen. In den Lagerhäusern, in denen die tageszeitlichen Temperaturschwankungen weniger als 1 ˚C betrugen, war für eine vollständige Befallsbeseitigung die kombinierte Exposition bei Temperaturen unter 7 ˚C für 9 bis 10 Wochen und unter 6˚C für 1 bis 2 Wochen notwendig. Die Temperaturen in den Tabakkisten entsprachen ungefähr den gleitenden Durchschnittsaußentemperaturen über 7 Tage, lagen aber um 1˚C darüber. Um die Larven in den Tabakkisten zu bekämpfen, sollten diese für 7 bis 8 Wochen Außentemperaturen unter 6 ˚C und für 3 bis 4 Wochen Temperaturen unter 5 ˚C ausgesetzt sein. In der Nähe der kritischen Bedingungen führten stärkere tageszeitliche Temperaturschwankungen zu höheren Überlebensraten im Winter. Diese Ergebnisse weisen darauf hin, dass die Larven auch in Gebieten, die kalt genug sind um normalerweise zu einer Vernichtung der Population zu führen, überleben können, wenn die Tagestemperaturen stark genug ansteigen. [Beitr. Tabakforsch. Int. 22 (2006) 303–306]

RESUME

La survie hivernale des larves de *Lasioderma serricorne* dans trois entrepôts de tabac et trois séchoirs a été étudiée sur cinq sites au Japon pour déterminer les conditions de température critique pour l'éradication de l'infestation en conditions naturelles, avec des variations de température saisonnières et journalières. Dans les entrepôts de tabac, dans lesquels les variations des températures journalières sont moins de 1 ˚C, l'exposition combinée aux températures au-dessous de 7 ˚C pour une durée de 9 à 10 semaines et aux températures au-dessous de 6 ˚C pour une durée de 1 à 2 semaines à l'intérieur des caisses s'est révélée nécessaire pour l'éradication. Les températures à l'intérieur des caisses correspondent à la variation moyenne des températures extérieures de 7 jours, étant de 1˚C plus élevée. Pour une éradication des larves dans le tabac, les caisses de tabac doivent être exposées à des températures extérieures inférieures à 6 ˚C pour une durée de 7 à 8

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semaines et au-dessous de 5 ˚C pour 3 à 4 semaines. Autour des conditions critiques, les variations des températures journalières ont abouti à une survie hivernale s accrue. Ce résultat suggère que les larves puissent survivre, même sur des sites suffisamment froids pour causer l'éradication de l'infestation, lorsque les températures diurnes sont suffisamment élevées. [Beitr. Tabakforsch. Int. 22 (2006) 303–306]

INTRODUCTION

The cigarette beetle is a cosmopolitan pest that is found throughout tropical, subtropical and warm-temperate regions allover the world. Its distribution is restricted by low temperature and low humidity (1). Under laboratory conditions, acclimated last-instar larvae (in the overwintering stage) required about 11 weeks at 5 ˚C for eradication (2). This result was observed in a small chamber with constant temperature. The extinction of this pest in tobacco hogsheads was demonstrated after the hogsheads had been exposed to constant temperatures of 4.4, 7.2, and 8.9 ˚C for 12, 20, and 32 weeks, respectively (3). Available studies under natural winter conditions with fluctuating temperatures have limited value. Winter extinction in tobacco hogsheads stored in an uncontrolled warehouse was demonstrated in Durham, North Carolina, where tobacco had been kept at temperatures lower than 4.4 ˚C for 90 days (4). Criteria for winter survival were not determined in that study. We examined winter survival associated with temperatures under natural situations in various areas to determine the conditions necessary and sufficient for eradication. At the same time, we evaluated the effect of diurnal temperature variations on survival of the cigarette beetle, *Lasioderma serricorne* (F.).

MATERIALS AND METHODS

Insects

The cigarette beetles used in this study were of our laboratory culture maintained on 10% yeast-added corn flour at 27 ˚C and 60% relative humidity. Breeding jars containing early fourth (final)-instar larvae (24 days after oviposition) were transferred to a 15 ˚C chamber and kept for a month for acclimation. After acclimation, 25 larvae were put into polystyrene vials (2.5 cm diameter × 5.0 cm high, with 100 µm-mesh gauze insets in the lid) with 1 g of corn flour and supplied for testing. After exposure, the vials were transferred to a 27 ˚C and 60% relative humidity chamber and kept for two weeks. Subsequently, the viability of the larvae was examined. Four vials (100 larvae) were supplied for each test.

Evaluation of winter mortality associated with temperatures

To determine the critical temperature conditions for eradication in tobacco warehouses, field experiments were conducted in three tobacco warehouses: One in Sukagawa [N37˚18', E140˚20'; a two-floor building of reinforced concrete – the first floor (1F) of work space without tobacco storage and the second floor (2F) with tobacco storage]; one in Tokyo (N35˚37', E139˚47'; the fourth floor of a five-floor building of reinforced concrete); and one in Yoro (N35˚17', E136˚33'; a one-store house built of autoclaved lightweight concrete). Four larvae-containing vials and one thermometer each were placed inside and outside the tobacco storage case, respectively. For "inside" measurements, the vials were put at the center of the upper surface of flue-cured tobacco in a 73 × 110 × 72 cm cardboard case; then another case was stacked upon it. The vials were at a distance of more than 30 cm from the inside surfaces of the case and 70 cm from the top and bottom of the stack. For "outside" measurements, the vials were put on the floor. Temperatures were recorded every one hour using a thermo recorder (TR-52; T & D Corp., Nagano, Japan) with a thermistor placed next to the vials. To evaluate the effect of the diurnal temperature variations on survival, experiments were conducted similarly in two sheds at Oyama (N36˚20', E139˚50'; a shed built of wood and one built of autoclaved lightweight concrete) and one at Saitama (N35˚54', E139˚37'; a mailbox fixed on the wall of a wooden house). At each location, experiments were performed during mid-November 2004 to mid-April 2005.

RESULTS AND DISCUSSION

Criteria for eradication in tobacco warehouses

Table 1 shows winter survival of larvae and five-day averages of "inside" and "outside" temperatures in three warehouses. The mean diurnal temperature ranges at all measured points in the warehouses were less than 1 ˚C. The critical threshold for eradication is assumed to be at conditions between those inside the tobacco case at Yoro (YT), which were the mildest conditions that gave 100% mortality, and those on the first floor at Sukagawa (S1F), which were the severest conditions that allowed survival. The temperature curves at these two locations were close to each other and the mean temperatures (December 1 to March 31) were almost equal, but the minimum temperature measured at YT was about 1 ˚C lower than at S1F. The number of days with mean temperatures lower than 8 ˚C was almost equal but different with temperatures lower than 7 ˚C and 6 ˚C.

In conclusion, we consider exposure of larvae to temperatures below 7 ˚C for 9 to 10 weeks and below 6 ˚C for 1 to 2 weeks (as observed inside the tobacco case at Yoro) as a requirement for eradication. Temperatures inside tobacco cases approximated the 7-day moving averages of the outside temperatures but were about 1 ˚C higher at the lower temperature range. Therefore, tobacco cases should be subjected to more severe outside conditions to disinfest the insects living inside. Closed tobacco cases should be exposed to temperatures lower than 6 ˚C for 7 to 8 weeks and below 5 ˚C for 3 to 4 weeks (as observed on the Yoro warehouse floor) to meet the eradication criteria.

Effect of diurnal temperature ranges on winter survival

Temperature conditions at four test locations were compared to evaluate the effect of diurnal temperature ranges

Table 1. Seasonal change of temperatures and winter survival of acclimated larvae of the cigarette beetle in three tobacco warehouses (December 2004 – March 2005)

	Tokyo		Yoro		Sukagawa [a]		
	Floor	Tobacco	Floor	Tobacco	1F	2F	Tobacco
			Mean temperature (℃)				
December 1–5	18.1	19.0	11.6	13.5	13.2	9.5	11.4
December 6–10	17.7	18.3	10.2	12.7	12.5	9.4	10.4
December 11–15	17.3	17.9	10.6	12.1	10.7	8.3	9.6
December 16–20	16.7	17.3	9.6	11.2	10.2	7.7	8.5
December 21–25	15.9	16.7	8.4	10.7	10.0	6.7	7.9
December 26–31	14.8	15.8	6.8	9.3	9.3	5.1	6.8
January 1–5	13.1	14.5	5.5	7.4	8.0	3.3	5.1
January 6–10	12.6	13.4	5.4	6.6	7.3	2.6	4.1
January 11–15	12.0	12.7	5.5	6.1	6.8	2.8	3.5
January 16–20	11.6	12.2	6.3	6.4	6.7	3.2	3.6
January 21–25	11.6	12.0	5.0	6.3	6.7	3.3	4.1
January 26–31	11.5	11.8	5.5	6.1	6.7	4.4	4.3
February 1–5	11.3	11.6	3.9	5.6	6.3	3.3	4.7
February 6–10	11.2	11.5	5.8	5.2	6.2	3.6	4.1
February 11–15	11.1	11.4	5.1	6.0	6.2	4.1	4.4
February 16–20	11.2	11.4	6.5	6.3	6.3	3.8	4.5
February 21–25	11.2	11.3	5.4	6.4	6.6	5.3	4.8
February 26–28	11.4	11.5	5.1	6.3	6.4	4.6	5.5
March 1–5	11.4	11.5	5.7	6.1	6.2	4.4	5.2
March 6–10	11.4	11.6	6.5	6.4	6.7	5.1	5.0
March 11–15	12.1	11.9	6.1	7.5	7.1	6.4	6.1
March 16–20	12.6	12.3	6.8	7.1	7.3	6.9	6.7
March 21–25	13.2	12.9	7.5	7.8	7.7	7.8	7.4
March 26–31	13.6	13.4	7.6	8.0	7.4	7.9	8.0
December 1– March 31	13.1	13.5	6.8	7.8	7.9	5.4	6.1
			Days with mean temperatures				
Lower than 8 ˚C	0	0	93	85	87	104	94
Lower than 7 ˚C	0	0	78	67	61	88	82
Lower than 6 ˚C	0	0	52	13	1	74	71
Lower than 5 ˚C	0	0	24	0	0	63	57
			Survival rate, %				
Mean ± SEM	90.0 ± 1.2	92.0 ± 1.6	0 ± 0	0 ± 0	11.0 ± 2.5	0 ± 0	0 ± 0

[a] The first floor (1F) of work space without tobacco storage and the second floor (2F) with tobacco storage.

Table 2. Effect of diurnal temperature variations on winter survival of acclimated larvae of the cigarette beetle (December 2004 – March 2005)

	Oyama		Saitama	Yoro
	Wooden	Concrete	Mailbox	Tobacco
		Mean temperature (℃)		
December 1 – March 31	7.2	7.0	7.2	7.8
Daily maximum	14.5	9.7	10.7	7.9
Daily minimum	2.1	5.3	4.1	7.7
Diurnal range	12.4	4.4	6.6	0.2
		Days with mean temperatures		
Lower than 7 ˚C	64	63	65	67
Lower than 6 ˚C	46	47	47	13
Lower than 5 ˚C	24	19	27	0
		Survival rate, %		
Mean ± SEM	99.0 ± 1.0	0 ± 0	69.0 ± 5.7	0 ± 0

on winter survival (Table 2). Mean temperatures in the wooden shed and the concrete shed at Oyama (OW and OC) and in the mailbox at Saitama (SM) were 7.0 to 7.2 ˚C, which was slightly lower than in the tobacco case at Yoro (7.8 ˚C). Periods with daily mean temperatures lower than 7 ˚C at OW, OC, and SM were almost as long as at YT; those with temperatures lower than 6 ˚C were much longer. The low-temperature periods certainly met the criteria for eradication described above. However, the larvae survived pretty well at OW and SM. The highest survival rate was seen at OW, where nighttime temperatures were the lowest while daytime temperatures were the highest. This observation suggests that cigarette beetle larvae may survive in areas where daytime temperatures rise sufficiently, even if it is cold enough to normally cause eradication of the insects. Obviously, larger diurnal temperature ranges cause higher winter survival rates even under sufficiently severe temperature conditions. The similar phenomenon has been reported for the grain weevil, *Sitophilus granarius*: Longer survival time has been shown at fluctuating temperatures between 0 and 10 ˚C, than at a mean constant (5). The mechanisms responsible for low-temperature (nonfreezing) injury remain largely unknown (6), but the results presented here indicates that chilling damages of the cigarette beetle can be recovered by intermittent temperature increases.

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