Suppression of the population of *Lasioderma serricorne* in stored tobacco by relocation of warehouses to cooler areas

Imai, T.*#
Leaf Tobacco Research Center, Japan Tobacco Inc.; Oyama, Tochigi 323-0808, Japan.
Email:toshihiro.imai@jt.com

* Corresponding author
# Presenting author

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Abstract

To suppress populations of cigarette beetles, *Lasioderma serricorne,* during winter, domestic tobacco warehouses in Japan have been relocated since 2004. Warehouses located in warmer tobacco-cultivated areas were closed, and new ones were constructed in places where the daily mean temperature is below 5ºC for over 70 d per year, a value chosen based on lethal low temperature conditions determined under constant laboratory and fluctuating field situations. In 2008, with relocations almost complete, the total number of beetles captured in pheromone traps in all warehouses had decreased by 98% compared to the 2001-2002 levels. Domestic tobacco production and the number of warehouses were reduced by 40% during the time.

Keywords: *Lasioderma serricorne*; Cigarette beetle; Tobacco warehouse; Low temperature; Winter survival

1. Introduction

The cigarette beetle, *Lasioderma serricorne* (F.) (Coleoptera: Anobiidae), is a cosmopolitan pest that is found throughout tropical, subtropical and warm-temperate parts of the world. It is the most problematic stored-tobacco pest in Japan. Pesticide application to stored tobacco and tobacco products is restricted, where phosphine fumigation is the only available method for disinfestation of warehouses. Nevertheless, phosphine-resistant beetles have continued to spread, and current fumigation techniques are becoming less effective (Rajendran and Narasimhan, 1994; Zettler and Keever, 1994). In addition to the emerging problem of resistance, public concern has been growing regarding the potential health and environmental hazards of pesticides. Consequently, non-chemical control methods have become increasingly sought as future pest-management strategies. Storage facilities that cool the air to 4ºC have been designed to eliminate this pest in stored tobacco (Childs et al., 1983; Beard et al., 1983; Beard et al., 1986); however, the cost of such facilities has prevented their construction.

In Japan, *L. serricorne* is prevalent in southwestern areas, but is not commonly found in northern areas. This fact suggests that the cigarette beetle is not fully adapted to temperate climates in Japan, and that the relocation of warehouses to cooler areas may reduce damage during storage without the need for cooling facilities. To identify the temperature conditions necessary to achieve suppression of the beetle population in storage facilities, beetle mortality was examined at constant low temperatures or under fluctuating field conditions. The conditions for beetle eradication were determined to be 11 wks at a constant temperature of 5ºC or 9-10 wks below 7ºC plus 1-2 wks below 6ºC under a natural winter situation (Imai and Harada, 2006; Imai and Tsuchiya, 2007). Based on these results, tobacco warehouses in Japan have been relocated from warmer tobacco-cultivated areas to cooler areas where the daily mean temperature is below 5ºC for over 70 d per year. The present paper describes the results of a supplementary laboratory test to verify the winter extinction conditions and the effect of warehouse relocation on the population of *L. serricorne*.

2. Materials and methods

2.1. Evaluation of mortality at constant low temperatures

Laboratory tests were performed as described in Imai and Harada (2006). Acclimated fourth (final)-instar larvae pre-exposed to 15ºC for one month were exposed to 7.5ºC and 10ºC for 4, 8, 12, 16, 20 and 24 wks, and their viability was checked. The 50% and 99% lethal times (LT_{50} and LT_{99}) were calculated

with the PriProbit (ver. 1.63) computer program developed by Sakuma (1998), which was downloaded from http://bru.gmprc.ksu.edu/sci/throne/.

2.2. Contour mapping of 5ºC/70-day lines

The mean of the daily temperature from 1971 to 2000 at 255 meteorological data points over central and western areas of Japan were taken from the Japan Meteorological Agency website:

(http://www.data.jma.go.jp/obd/stats/etrn/index.php).

Contour analysis was done for the annual number of days with a mean temperature below 5ºC using the Surfer 8.0 computer program (Golden Software Inc., Golden, CO, USA).

2.3. Monitoring data in tobacco warehouses

The appearance of adult *L. serricorne* in tobacco warehouses was monitored by JT Logistics Co. Ltd. using commercial pheromone traps (SERRICO, Fuji Flavor Co. Ltd., Tokyo, Japan). The traps were placed at a density of 1 trap per 200 m^2 in every warehouse. The annual monitoring data for the years 2001, 2002, 2007 and 2008 were supplied by JT Logistics Co. Ltd.

3. Results and discussion

3.1. Winter extinction conditions for L. serricorne

Table 1 shows the lethal exposure times at constant temperatures of 0, 5, 7.5 and 10ºC for the acclimated larvae of *L. serricorne*. These results coincide with the mortality data in tobacco hogsheads: the larvae in hogsheads were eradicated in 12, 20, and 32 wks at constant temperatures of 4.4, 7.2, and 8.9ºC, respectively (Childs et al., 1968). Almost three months were required to eradicate the acclimated larvae at 5ºC and half a year was required at 7.5ºC. Because the latter condition is not achievable in natural situations in temperate areas, the critical temperature × duration for this pest to overwinter in temperate areas should be around 5ºC × three months. An actual winter extinction under fluctuating natural situations occurred in milder conditions than those expected from laboratory data at constant temperatures; 9-10 wks below 7ºC plus 1-2 wks below 6ºC (Imai and Tsuchiya, 2007). During that experiment, test insects were exposed to the atmospheres of warehouses for five months (from mid-November to mid-April). Under practical warehouse conditions, exposure to sublethal low temperatures before and after deep winter accelerates the lethal effect of low temperatures.

Table 1 Lethal exposure time for acclimated larvae[a] of *Lasioderma serricorne* at constant low temperatures.

Temperature, ºC	LT_{50} (fiducial limits), day	LT_{99} (fiducial limits), day
0[b]	21 (19–25)	47 (43–55)
5[b]	22 (18–25)	78 (60–117)
7.5	43 (32–53)	188 (113–150)
10	64 (50–77)	226 (180–358)

a Larvae were exposed to 15ºC for one month before exposure to each low temperature;
b Data were reproduced from Imai and Harada (2006).

3.2. The effect of warehouse relocation to cooler areas on the population of L. serricorne

Based on the laboratory and field experimental data on lethal low-temperature conditions, tobacco warehouses in Japan have been relocated since 2004. In 2001 and 2002, approximately 60,000 t of tobacco were produced domestically and stored in 22 warehouses located near the cultivated areas; 10 of the warehouses were in Kyushu, the southwestern island of Japan (Fig. 1a). During that time, more than 1,000 beetles were captured annually, and phosphine fumigation was applied twice per year, in May and August. Since that time, domestic tobacco warehouses in warmer areas have been closed, and new ones have been constructed in places where the daily mean temperature is below 5ºC for over 70 d per year (Fig. 1b). Regular fumigation has not been applied since 2005. The total number of adult *L. serricorne* captured in monitoring traps in all warehouses in 2008 decreased by 98% compared with those in 2001 and 2002, whereas domestic tobacco production and the number of warehouses have dropped by 40% during the time (Table 2). The trap catch is a good index of pest population, although it is affected by temperature condition. The flight behavior and trap catch of *L. serricorne* are suppressed below 20ºC (unpublished data). The mean temperatures exceeded 20ºC at least three months (mid-June to the end of

September) in every location that the warehouses were located, and the reduction in number of catches per trap should reflect population decrease. Even though pests accompanying tobacco from processing plants can not be prevented from occasional entering these warehouses, the results indicate that the overall population has remained low almost all year.

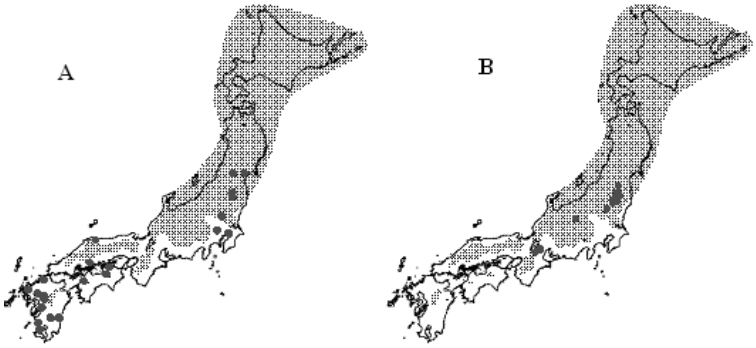

Figure 1 The distribution of domestic tobacco warehouses in Japan (A, 2002; B, 2008). The circles show the locations of domestic tobacco warehouses and the gray area shows the area experiencing mean temperatures below 5ºC for at least 70 days.

Table 2 Annual domestic tobacco production, the number of warehouses and total number of *Lasioderma serricorne* adults captured by pheromone traps in all domestic-tobacco warehouses in Japan.

Year	Leaf production, t	No. warehouses	Total *L. serricorne* caught	*L. serricorne* caught/trap/year
2001	60,565	22	1,916	1.53
2002	58,174	22	1,676	1.34
2007	37,803	15	203	0.35
2008	38,484	12	37	0.07

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