

**TOMICUS PINIPERDA (COLEOPTERA: SCOLYTIDAE) WITHIN
AND BETWEEN TREE MOVEMENT WHEN MIGRATING TO
OVERWINTERING SITES**

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ABSTRACT

Tomicus piniperda (L.) (Coleoptera: Scolytidae) is a univoltine bark beetle that conducts maturation feeding inside shoots of pine (*Pinus*) trees during summer and fall. In the northern portion of its range, where freezing winter temperatures occur, adults overwinter in the outer bark at the base of live pine trees. In the present study, we investigated how adults move to their overwintering sites. We collected infested shoots in late October 2001, applied fluorescent powder to the entrance holes of the feeding tunnels, and attached about 50 shoots to each of 8 test trees in early November. We installed interception traps around the trunks of four test trees, and placed barrier pitfall traps in the soil around the other four test trees. The eight test trees were cut 10 days later and an additional 32 neighboring trees, 4 trees per test tree, were cut in late November. Another 22 "control" trees, which were 8-17 m from any test tree, were cut in early December. We debarked the lower trunk of each cut tree, collected all overwintering adults, and inspected them for powder, using a dissecting microscope and ultraviolet light. Overall, we recovered 56% of the estimated number of released beetles (221 of 392) on the eight test trees. Powder was present on 97% of the 221 recovered beetles. The trunk traps intercepted 66% of all adults recovered on the four trees with trunk traps. No adults were recovered in the pitfall traps. On the 32 nearby trees, 6 of the recovered 129 overwintering adults had powder. No powder was found on any of the 53 overwintering adults recovered from the 22 control trees. There were significantly more overwintering adults found on the 32 trees that neighbored the 8 test trees (4.0 adults/tree) compared with the 22 control trees that were further away (2.4 adults/tree). The sex ratios of overwintering adults were similar among the three groups of trees. Daily maximum temperatures exceeded the flight threshold of *T. piniperda* (10-12°C) on each day during the 10-day field study. Results indicate that most adults overwinter on the same tree where they last shoot fed, but some adults will fly to nearby trees to overwinter when temperatures exceed the flight threshold of *T. piniperda*.

INTRODUCTION

Tomicus piniperda (L.) (Coleoptera: Scolytidae), commonly known as the pine shoot beetle, is a major pest of pine (*Pinus*) throughout the northern hemisphere. This bark beetle is native to Asia, Europe, and parts of North Africa (Bakke 1968, Långström 1983, Salonen 1973, Ye 1991), where it can cause severe growth loss and at times tree mortality (Amezaga 1996, Hui and Lieutier 1997, Kaplan and Mokrzycki 1988, Långström et al 2001, Salonen 1973). Established populations of *T. piniperda* in North America were first discovered in 1992 (Haack and Poland 2001), and as of September 2003, *T. piniperda* occurred in 13 US states and 2 Canadian provinces (NAPIS 2003).

Tomicus piniperda completes one generation per year throughout its worldwide range (Bakke 1968, Haack and Poland 2001, Poland and Haack 2000,

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Ye 1991). In spring, sexually mature adults fly from their overwintering sites and breed in suitable host material such as recently cut pine trees and stumps, and occasionally in live pine trees that have been stressed (Hui and Lieutier 1997, Kaitera and Jalkanen 1994, Kaplan and Mokrzycki 1988, Ye 1991). Progeny adults emerge in early summer and fly to the crowns of pine trees where they conduct maturation feeding by tunneling inside shoots. Shoot feeding continues into autumn, but as freezing temperatures occur, adults begin to exit the shoots and move to their overwintering sites inside the outer bark along the lower trunk of live pine trees (Långström 1983, Petrice et al. 2002, Salonen 1973).

Overwintering behavior is an interesting feature of *T. piniperda*'s life history. Haack et al. (2001) and Petrice et al. (2002) stated that in the Great Lakes region, *T. piniperda* adults apparently walk along the branches and trunk to the base of the tree on which they had last shoot fed. The first adults to reach the base of the tree typically select overwintering sites within 10 cm of groundline (Petrice et al. 2002). Although Långström (1983) provided evidence that some adults actively walk down the trunks of pine trees to overwinter, we have found no studies that focused on this particular aspect of *T. piniperda*'s overwintering behavior.

From an evolutionary viewpoint, it would be advantageous for *T. piniperda* adults to have multiple methods available to reach their overwintering sites, although each method could vary in energy expenditure and risk. Moreover, the method selected by any given adult may be influenced by the location of the beetle within the crown of the tree, the size of the tree, and the ambient temperatures. For example, (a) do *T. piniperda* adults only walk along the branches and trunk to reach the base of the tree on which they last shoot fed, (b) do some adults fall to the ground and walk to the nearest pine tree, or (c) do some adults fly to the tree base? Furthermore, if some adults do fly to their overwintering sites, do they fly to the base of the same tree on which they last shoot fed or to different trees? Långström (1983), working in Sweden, believed that *T. piniperda* adults usually did not fly to the lower trunks of trees to overwinter given that fall temperatures in Sweden were usually not warm enough to support adult flight. In the present study, we focused on how *T. piniperda* adults moved to their overwintering sites by hand-placing known numbers of *T. piniperda*-infested shoots on pine trees in the fall and then closely monitoring the subsequent movement of the adults.

MATERIALS AND METHODS

The field study was conducted during fall 2001 in a Scots pine (*Pinus sylvestris* L.) Christmas tree farm near Mason, Ingham County, MI (42° 34' N, 84° 22' W). The tree farm has about 12 ha of pine trees, and *T. piniperda* has been present there since the early 1990s. In the fall of 2001, local *T. piniperda* populations at the tree farm were relatively low, with most trees having only one or two current-year infested shoots.

We collected *T. piniperda*-infested shoots in late October 2001 in a heavily infested Scots pine Christmas tree farm near Orland, IN (41° 43' N, 85° 10' W), which is about 112 km south of the Mason field site. We chose this more southerly field site, where temperatures had been warmer, to ensure that a higher percentage of the current-year attacked shoots would still contain adults. We collected shoots that had one or more *T. piniperda* entrance holes along the current-year growth and still had green to yellowish-green foliage, suggesting recent attack (Haack et al. 2001, Kauffman et al. 1998, Långström 1983). The shoots were placed individually in plastic bags in the field, returned to the laboratory, and refrigerated at 4-5°C for a few days until placed back in the field. We specifically selected shoots that had fresh boring dust at the entrance hole of one of the tunnels, strongly suggesting that an adult beetle was still inside. Before tying about 50 shoots to each of the eight test trees (Table 1), we brushed orange fluorescent powder over the entrance hole to all tunnels so that

Table 1. Summary data for each Scots pine test tree, including tree size data, the number of powdered *T. piniperda*-infested shoots placed on each tree on 4 November 2001, and the number of *T. piniperda* adults recovered at different locations on each test tree 10 days later in a Christmas tree plantation near Mason, MI.

Parameter	Trees without trunk traps				Trees with trunk traps				Total
	1	2	3	4	5	6	7	8	
Tree height (m)	3.0	3.0	4.0	2.8	3.2	3.3	2.8	3.1	
Tree diameter at breast height (cm)	4.1	3.9	8.4	4.1	4.9	5.0	4.7	4.9	
Tree diameter at groundline (cm)	9.0	8.8	12.2	9.6	9.4	9.9	9.1	8.5	
Height above groundline where trunk trap was attached to trunk (cm)					62	95	67	82	
Height trunk cut below groundline (cm)	32	32	29	26	32	31	26	22	
Height trunk cut above groundline (cm)	4	6	5	4	6	4	6	7	
Maximum height above groundline where an overwintering adult was found (cm)	11	28	10	11	13	11	14	15	
No. powdered shoots attached	49	49	51	51	49	50	51	49	399
No. powdered shoots with an adult still inside at end of study	0	1	1	2	0	2	0	1	7
No. adults estimated to have exited from shoots	49	48	50	49	49	48	51	48	392
No. adults caught in trunk traps					13	17	15	15	60
No. adults in bark near trunk traps					0	0	8	6	14
No. powdered adults at tree base	21	27	26	31	16	5	5	10	141
No. adults at tree base with no powder	0	0	4	0	0	1	1	0	6
No. frass piles at tree base with powder	21	24	14	12	13	6	3	8	101
Total number of adults found on tree	21	27	30	31	29	23	29	31	221
Percentage of adults recaptured (%)	43	56	60	63	59	48	57	65	56

the adult beetles would mark themselves with the powder when they later exited from the tunnels. The powdered shoots were distributed evenly throughout the crown of each test tree. Each powdered shoot was attached tightly to another current-year shoot on the test trees, using plastic-coated wire. When finished, we dissected 25 extra shoots that had frass present at the entrance hole and inspected them for *T. piniperda* adults.

The eight test trees were 2.8-4.0 m tall and 3.9-8.4 cm in diameter at breast height (1.4 m above groundline; Table 1). The test trees were at least 15 m apart with a minimum of three other similarly sized trees between any two test trees. Before adding the powdered shoots, we inspected each test tree and removed all current-year shoots that had *T. piniperda* tunnels.

To allow easier access to the trunk, we removed all branches along the lower 1.5-1.7 m of trunk on each test tree. The eight test trees were divided randomly into two groups of four trees each. In one group, a funnel-like trap was installed around the lower trunk of each tree. The objective of the funnel was to intercept all adults that walked downwards along the trunk and to direct them into the plastic cup where they would be captured. The plastic funnels were 20 cm in length and 20 cm in diameter at the widest end. Holding the wide end of the funnel at about a 70° angle to the tree trunk, we cut away a circular section of the funnel that closely approximated the diameter of the tree trunk. Each funnel was placed completely around the lower trunk (Table 1), positioned to point downward at a 70° angle, and then nailed to the trunk with aluminum nails. We then used silicone caulk to fill any gaps between the tree trunk and funnel where beetles

could pass. We attached a small plastic cup with a screw-on lid over the spout end of each funnel. The funnel and lid were attached with silicone caulk after a hole was cut through the lid and pushed over the spout until snug.

No trunk traps were installed on the second group of trees; however, we encircled each of these four trees with plastic garden edging in the soil to make barrier pitfall traps in the form of two concentric rings. The objective of using pitfall traps was to capture any *T. piniperda* adults that dropped or flew to the soil and then walked to the base of the tree. The garden edging was 10 cm tall and was inserted into the soil to a depth of about 4 cm. The inner ring was located about 20-30 cm from the tree base and the outer ring was located at a distance that followed the edge of the crown, a radius of about 1.5 to 2 m. For each of these four trees, 10 cups were inserted into the soil along the walls of the garden edging. The plastic cups were 15 cm tall and 10 cm wide at the mouth end. Six cups were placed evenly along the perimeter of the outer ring, three on the inside and three on the outside of the edging. Similarly, four cups were placed along the inner ring, two on the inside and two on the outside. The cups were inserted in the soil so that the mouth of the cup was flush with the soil level. We used a multiple cup design for the pitfall trap (Reeves 1980) with no preservatives in the cups.

All trunk traps, pitfall traps, and test shoots were set up on 4 November 2001. Funnel traps and pitfall traps were checked daily for *T. piniperda* adults over the next 10 days. All adults collected were inspected under a dissecting microscope for the presence of fluorescent powder, using an ultraviolet light. The presence of powder on a beetle was considered evidence that the beetle had exited from a powdered shoot.

We cut the eight test trees on 14 November 2001. The basal 26-32 cm of each trunk, cut at least 4 cm below groundline (Table 1), and the portion of the four trunks that contained the trunk traps, were placed in individual plastic bags and returned to the laboratory and refrigerated. In addition, before cutting each test tree, we marked the location of groundline on the bark surface and then collected the surface soil within a 30-cm radius of the trunk to a depth of 3 cm. The soil was placed in labeled plastic bags and refrigerated until inspected for *T. piniperda* by sifting. All test shoots were collected from the eight test trees, bagged individually, and later cut open and inspected for any *T. piniperda* adults that were still inside. In the laboratory, we slowly removed the bark from each trunk section. When the entrance to a tunnel was exposed, we first inspected the frass near the entrance hole for fluorescent powder and then recorded the distance from the entrance hole to where groundline had been. After that, we removed the overwintering adult from the tunnel and inspected it for fluorescent powder. Later, the sex ratio was determined from a sub-sample of adults from each tree.

In late November 2001, we cut the nearest four pine trees around each of the eight test trees for a total of 32 trees. As described above, we removed the lower 30 cm of trunk from each tree, bagged and refrigerated the trunk sections, and later inspected each for overwintering adults and the presence of fluorescent powder. Similarly, in early December 2001, we cut and treated as described above another 22 "control" Scots pine trees that were 8-17 m from any of the original eight test trees. The sex ratio was determined separately for adults from the "nearby" and "control" trees, using a sub-sample of adults from each tree.

Statistical analyses. One-way analysis of variance (GLM procedure, SAS Institute 1988) was used to test for significant differences between (a) the mean number of *T. piniperda* adults found on trees with and without trunk traps, (b) the mean number of *T. piniperda* adults found at the base of trees with and without trunk traps, and (c) the mean number of *T. piniperda* adults found at the base of the 32 "nearby" trees vs. the 22 "control" trees. The sex ratios were compared among the test, nearby, and control trees using Chi-square analysis. A significance level of $\alpha=0.05$ was used in all analyses.

RESULTS AND DISCUSSION

When we sampled the 25 extra shoots, we found a single *T. piniperda* adult inside each tunnel that had frass present at the entrance hole to the tunnel. Therefore, we feel confident that each shoot that we placed on the test trees contained one *T. piniperda* adult. Overall, we placed 49-51 powdered shoots on each of the eight test trees for a total of 399 shoots (Table 1). At the end of the 10-day study period, we found that 392 of the powdered shoots were empty and 7 still contained one live adult each (Table 1). These results indicate that almost all (98%) adults left the shoots during the 10-day field study.

***Tomicus piniperda* collections in pitfall traps and soil.** No *T. piniperda* adults were found in any of the pitfall traps nor in any of the soil samples taken from around the base of the eight test trees. As mentioned above, we felt it was possible that some adults might first fly or drop to the ground and then walk to the nearest tree trunk to overwinter. Given that we caught no *T. piniperda* in the pitfall traps, we have no evidence that any of the adults dropped or flew to the ground and walked to their overwintering sites. It is possible, of course, that some beetles at first walked but when they encountered the garden edging they climbed or flew over it instead of walking along the edge and being trapped. Although no *T. piniperda* adults were collected in the pitfall traps, dozens of other arthropods (e.g., Carabidae, Formicidae, isopods, spiders) were collected in each trap, indicating that the traps effectively captured many groups of invertebrates.

At times, infested shoots fall to the ground in autumn while *T. piniperda* adults are still inside the tunnels (Långström 1983, Salonen 1973). Such adults would then have to fly or walk to a nearby tree to locate an overwintering site, or remain in the shoots. In the present study, no *T. piniperda*-infested shoots were located beneath any of the eight test trees.

***Tomicus piniperda* collections on trees with trunk traps.** Overall, 60 *T. piniperda* adults (range = 13 to 17 adults/tree) were caught in the four trunk traps (Table 1). Most adults (85%) were captured during the first four days of the study: 10 adults were collected on 5 November, 1 on the 6th, 37 on the 7th, 4 on the 8th, 7 on the 12th, and 1 on 13 November. All adults collected in the trunk traps were well covered with orange fluorescent powder, indicating that many *T. piniperda* adults did walk down along the trunk to overwinter and that our method of dusting the tunnel entrance holes worked successfully. However, given that we used the same color of powder on all trees, it is possible that a marked adult from one test tree was captured on another test tree. Nevertheless, we consider the chances of this happening to be low given that the test trees were at least 15 m apart, there were at least three other pine trees between any two test trees, and there were thousands of other pine trees in the plantation. Similarly, it is possible that some adults flew from the canopy branches towards the tree base and were inadvertently captured in the trunk traps. Again, although possible, we believe this scenario is unlikely given that the top of the funnel was usually within 50 cm of the base of the crown and that the crown was much wider in diameter than the trap. Therefore, we believe that nearly all adults collected in a trunk trap were adults that had originated from that same tree and that they were captured while walking down the trunk. As mentioned earlier, Långström (1983) also captured *T. piniperda* adults in traps as they walked down the tree trunks to locate overwintering sites in a study conducted in Sweden. The present study provides further evidence that many *T. piniperda* adults walk along the trunk to their overwintering sites at the tree base.

In two of the four trees with trunk traps, *T. piniperda* adults were found inside the outer bark along the trunk where the funnel was attached to the trunk. Eight adults were found on one of these trees and six adults were found on the other (Table 1). Orange powder was detected on the integument of each of these 14 adults, indicating that they had originated from powdered shoots. However, the amount of powder on any of these 14 adults was much less than

that found on any of the 60 adults captured in the actual trunk traps. A few pine needles and bark flakes had fallen into the funnels on the two trees where adults had entered the bark at the base of the funnel. Possibly these adults assumed they had reached the base of the tree when they encountered the needles and bark flakes in the funnel and thus were stimulated to enter the bark although they were still 0.7-0.8 m above the ground. After the field study ended, the four trunk traps were carefully inspected for fluorescent powder under a fluorescent lamp. Powder was found on the inner surface of all four trunk traps as well as along the outer rim of one funnel, suggesting that some *T. piniperda* adults were able to walk on the funnel's inner surface and possibly escape. Therefore, the number of adults captured in and around the trunk traps is likely less than the total number of adults that actually walked down the trunks on these four trees.

Assuming that each powdered shoot that was empty at the end of the study represented a single *T. piniperda* adult that had left the shoot in search of an overwintering site, then the total number of adults collected in and around each trunk trap represented 27-45% (mean = 38%) of the number of adults released on those four trees. Overall, these results indicate that either our traps were no more than 45% effective, assuming all adults walked down the trunk, or walking along the trunk was not the only method used by the adults when they moved to their overwintering sites.

***Tomiscus piniperda* collections at the base of the test trees.** Overall, we collected 147 *T. piniperda* adults from their overwintering tunnels in the outer bark of the lower trunk of the eight test trees (Table 1). We found fluorescent powder on 141 (96%) of the recovered adults, indicating that almost all of these adults had originated from powdered shoots. The amount of powder detected on these 141 adults was variable: some adults were heavily coated with powder, while others had only a few specks of powder. It is possible that the six adults on whom we could not find any powder still originated from the powdered shoots. However, in these six cases, the adults may have rubbed the powder off as they tunneled into the bark. In fact, orange fluorescent powder was found in 69% of the frass piles (101 of 147) at the entrance hole to the tunnels where the adults were overwintering (Table 1).

As expected, significantly more adults were found at the bases of the four trees that lacked trunk traps (mean = 27 adults/tree) compared with the four trees with the trunk traps (mean = 10; $F = 29.6$; $df = 1,6$; $P < 0.002$). Considering the number of powdered shoots placed on each tree that later were found to be empty and the number of adults found at the base of each tree, both with or without powder, then the proportion of recovered adults ranged from 43 to 63% (mean = 56%) for the four trees that lacked trunk traps vs. 12 to 33% (mean = 19%) for the four trees with trunk traps. When we combined the number of adults found at the base of the trees with the number collected in or around the trunk traps, the proportion of recovered adults per tree increased to 48-65% (mean = 57%) for the four trees with trunk traps, making it comparable with the four trees without trunk traps (mean = 28 adults/tree; $F = 0.07$; $df = 1,6$; $P < 0.81$). Given that so many adults still reached the base of the four trees with trunk traps indicates that several adults either dropped from the canopy and walked to the base, flew to the base, or somehow bypassed the trap and reached the base. Nevertheless, considering all the adults that were later collected on the eight test trees, we still could not account for 44% (171/392) of the estimated number of released adults.

Number of infested shoots and overwintering *T. piniperda* on nearby trees. As mentioned above, we cut the four trees that were closest to each of the eight test trees and inspected them for *T. piniperda* adults. Overall, we found 129 overwintering adults along the lower trunks of the 32 nearby trees. No current-year, naturally infested shoots were found under any of these 32 trees, indicating that no infested shoots had fallen. For each set of four trees, we found 6-27

overwintering adults but only 0-5 current-year *T. piniperda*-infested shoots (Table 2). The number of infested shoots was always less than the number of adults found on any of the 32 nearby trees, suggesting that adults from other trees were overwintering on these trees. On average, there were 4.0 (± 0.6 SEM) *T. piniperda* adults at the base of each of the nearby trees. Of the 129 overwintering adults found on the nearby trees, we found six *T. piniperda* adults on three separate trees that were distinctly marked with fluorescent powder (Table 2). This observation proves that some *T. piniperda* adults actively moved to other trees to overwinter, most likely by flying. It is likely that many of the 123 recovered adults that lacked powder had still originated from the eight test trees, but any powder that was present on their bodies was lost when the adults moved to the nearby trees and tunneled into the bark. In fact, we did find powder on the bark surface at the entrance of one tunnel but no powder was found on the adult beetle removed from inside that tunnel.

Number of overwintering *T. piniperda* in the control trees. We found 53 overwintering adults at the bases of the 22 control trees, which were 8-17 m away from any of the eight test trees. On average, there were 2.4 (± 0.3) *T. piniperda* adults/tree on the 22 control trees, which was significantly less ($F = 4.6$, $df = 1, 52$; $P < 0.036$) than the mean number of beetles on each of the 32 nearby trees (4.0 adults/tree). These results further suggest that many of the adults that were found at the base of the nearby trees had originated from the test trees.

Sex ratio. The sex ratio was close to 50:50 for the overwintering *T. piniperda* adults that were collected on the three groups of trees. Based on a subsample of adults, 48% ($n = 142$) of the adults collected on the test trees were female, 55% ($n = 65$) were female on the nearby trees, and 53% ($n = 17$) were female on the control trees. The sex ratios were not significantly different between the adults collected on the test trees and nearby trees (Chi-square = 0.73, $df = 1$, $P > 0.39$), nor between the nearby trees and control trees (Chi-square = 0.009, $df = 1$, $P > 0.92$). Although we do not know the sex ratio of the adults that were inside the shoots that were placed on the test trees, we assume it was close to 50:50. Given that assumption, the sex ratios observed on the three sets of trees in this study indicate that both males and females behave similarly when seeking overwintering sites.

Fall weather conditions in 2001. The relatively high rate of apparent dispersal from the eight test trees may reflect the unusually warm weather conditions that occurred during the 10-day study period in November 2001. In fact, daily maximum temperatures were 10°-16°C during the entire 10-day

Table 2. Summary data by test tree for the four Scots pine trees, felled and inspected in late November 2001, that were growing nearest to each of the eight test trees in a Christmas tree plantation near Mason, MI.

Parameter	Trees without trunk traps				Trees with trunk traps				Total
	1	2	3	4	5	6	7	8	
No. nearby trees felled and inspected	4	4	4	4	4	4	4	4	32
Mean distance from test tree to 4 nearby trees (m)	2.0	2.3	2.4	2.2	2.0	2.2	2.2	2.2	
Total no. infested shoots found on nearby trees	4	3	1	5	2	2	0	2	19
Total no. adults found at bases of nearby trees	27	17	6	27	12	17	11	12	129
No. of adults with powder on nearby trees	0	2	0	0	0	1	3	0	6

period in 2001 (Fig. 1), warm enough each day to support adult flight given that *T. piniperda*'s flight threshold temperature is 10°-12°C (Bakke 1968, Haack and Lawrence 1995, Haack et al. 1998, Poland et al. 2002). In another field study in Michigan, Haack et al. (2000) reported that *T. piniperda* adults actively flew and initiated new shoot-feeding tunnels from early April through early November in 1994. Had daily air temperatures during our 10-day study period in 2001 been below *T. piniperda*'s flight threshold, then we would have expected to collect a higher proportion of the adults on the original eight test trees. Two earlier field studies at a single site in Indiana provide supporting evidence for this contention (Haack and Lawrence 1997, Haack et al. 2001). In these studies, where additional shoots were added to selected Scots pine test trees but without using any powder, the total number of *T. piniperda* adults found at the bases of test trees represented 80% of the number of infested shoots in a 1992 study (85 adults and 106 shoots on 4 test trees; Haack et al. 2001) and 78% of the infested shoots in a 1993 study (251 adults and 320 shoots on 12 test trees; Haack and Lawrence 1997). In those two years, almost all *T. piniperda* adults left the shoots during the 31-day period from 15 October to 14 November (Haack et al. 2001). During those 31 days, daily high temperatures were $\geq 10^{\circ}\text{C}$ on 18 days (18/31 = 58%) in 1992 and 21 days (68%) in 1993, based on weather records from Prairie Height, IN, which is about 8 km from the Orland, IN, study site in the present study. Therefore, in both 1992 and 1993, *T. piniperda* adults had many opportunities to fly to other trees but most adults (78-80%) apparently still overwintered on the same tree on which they last shoot fed. However, in the present study, when daily high temperatures exceeded *T. piniperda*'s flight threshold on each day during the 10-day study, we recovered only 56% of the adults (221 adults from 392 shoots) on the original eight test trees. These observations suggest that a greater percentage of *T. piniperda* adults will fly to other trees to overwinter when air temperatures are consistently warm enough to support flight during the active period of fall shoot departure.

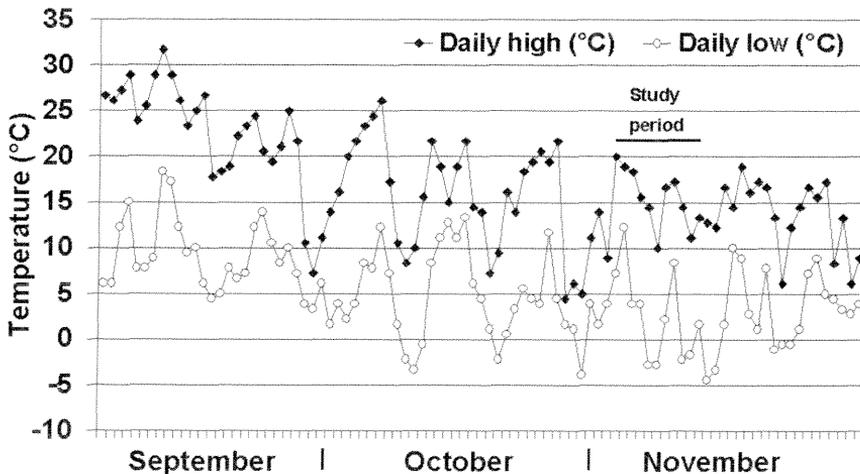


Fig. 1. Maximum and minimum daily air temperature from 1 September through 30 November 2001 in East Lansing, MI (42° 40' N, 84° 29' W; about 9 km from the Mason, MI, field site). The horizontal bar represents the study period during 4-14 November 2001.

Overall, our study results indicate that most *T. piniperda* adults will overwinter on the same tree on which they last shoot fed, and most of these adults will reach their overwintering sites by walking down the trunk. In addition, our results indicate that when temperatures are warm enough to support adult flight, many adults will actively fly to other trees to overwinter. Our study did not, however, provide evidence that adults drop to the ground and walk to nearby trees to overwinter.

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