Imidacloprid Chemigation for Control of the California Prionus Beetle in Utah Sweet Cherry Orchards

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Objective

Evaluate the efficacy of a spring imidacloprid application (Admire™) for suppression of root-boring *Prionus* larvae in mature sweet cherries. Investigate the distribution of larvae in the root system of sweet cherry trees.

Justification

In northern Utah, a cerambycid beetle, also known as the giant California Prionus (*Prionus californicus*), has been an occasional problem for stone fruit growers. In more recent years, however, cherry growers (particularly those in Box Elder County, UT) have had to pull out established cherry trees (6-13 years old) after the trees experienced a relatively rapid (3-4 years) decline. Part of this can be attributed to a multi-year drought and extreme summer temperatures, but investigations of trees in decline have revealed dense infestations of root-feeding *Prionus* larvae. The 3-4 year period of decline of these cherry trees corresponds with the typical development time of *Prionus* (3-5 years), though any given tree probably hosts multiple generations of beetles. Infestations tend to be on trees growing in highly drained soils, such as the sandy, rocky soils common to Box Elder County. Highly drained soils can cause greater drought-stress because the water rapidly percolates out of the root zone. This situation is likely a common one along the slopes of Box Elder County's Fruitway, and the stressed trees may be more vulnerable to *Prionus* infestations. The problem is likely exacerbated by the fact that many backyard and commercial orchards are in close proximity to each other, as well as to the surrounding natural habitats along mountain foothills and "benches." This phenomenon appears to permit a source-sink relationship to develop, which allows re-infestation even in highly managed commercial orchards.

To-date, there is little documentation of highly effective chemical controls for *Prionus* beetles (and other root-boring orchard pests). Currently registered materials are directed toward the adult *Prionus* beetle, and this approach is likely to miss segments of the generation because the timing and full duration of the adult emergence is difficult to determine (commercial pheromone traps do not yet exist). An insecticide that can be delivered to the soil and roots of an infested tree would allow for multi-generational mortality and theoretically, very high suppression of the root-feeding immature stages. Imidacloprid is a proven neo-nicotinoid insecticide that has been effective against a wide range of insect pests, including various Coleoptera. Recent work involving chemigation of imidacloprid in grape vineyards (for vine mealybug) and ornamental ash trees

(emerald ash borer) suggests that this method of delivery holds promise for control of less accessible pest species. Imidacloprid is moderately soluble in water, stable and persistent in soil, and upwardly systemic in plants. As a soil-applied insecticide in cherry orchards, it is expected to provide suppression of *Prionus* larvae.

Methods

Experimental design and treatments

In the spring of 2004, a trial was set up to test the efficacy of imidacloprid for the control of *Prionus* larvae in a 5-acre sweet cherry block (var. 'Bing' and 'Lambert') at Pettingill Farms in Willard, UT (Box Elder County). The soil at this location is a sandy loam, planted to sweet cherries the last 14 years. Eight mature trees (10-14 years old) were flagged for the trial in late-April of 2004. The trees chosen for the trial showed signs of significant decline (canopy dieback) which can be symptomatic of severe *Prionus* infestations. The experimental design was a randomized complete block with two replicates. Each replicate contained two treated and two untreated trees (Fig. 1), which provided a total of eight trees for the trial (four control trees, four treated trees).

Imidacloprid, formulated as Admire™, was delivered to individual cherry trees as a soil-soak at a rate corresponding to 24 fl oz/A. The first irrigation at Pettingill Farms was initiated on the morning of May 12, approximately two weeks after sweet cherry shuck-fall. The cherry block was irrigated using ½-inch above-ground tubing with drip-emitters every 24 inches of tubing. There were eight emitters per tree (four on each side of a tree). Irrigation water was delivered in 12-hour sets. The imidacloprid treatment was applied three hours after the irrigation had begun on May 12, which provided nine hours of imidacloprid percolation. Since the cherry orchard was planted in an 18' × 18' configuration (134 trees/A), each treated tree received 0.179 fl oz of Admire (5.33 ml), which corresponded to a field rate of 24 fl oz/A. The per-tree volume of Admire (5.33 ml) had been mixed thoroughly in 32 fl oz DI water (947 ml). Underneath each of the eight emitters per tree, shallow pits were dug to contain the Admire solution. Four fl oz (118 ml) of the Admire solution was poured into each of the eight pits per treated tree, and the pits were covered soon thereafter.

From the date of the Admire treatment until the sampling dates for *Prionus* (14-16 July), each tree received approximately 1,440 gallons of water. Each emitter dripped at a rate of 5 gal/4 hours, and since water was delivered in 12-hour sets, each emitter delivered 15 gallons during an irrigation set. Trees were irrigated every 5 days beginning on May 12 (the date that agricultural water first became available for use in this region), so each tree should have received a total of 120 gallons of water every five days of the growing season. By July 14, there had been 12 irrigation events (and very little rain) which totals 1,440 gal/tree. The entire orchard was managed conventionally (chemical and fertilizer inputs), maintaining relatively healthy trees and maximizing harvestable fruit.

Sampling for Prionus larvae

Trees were destructively sampled on 14-16 July, 2004. After the irrigation lines had been moved aside, each tree was pulled out and the soil excavated using a backhoe. The soil

was excavated approximately four feet deep, creating an oval-shaped crater approximately 9 feet long (along the irrigation drip zone) and 4 feet wide. The loose soil was carefully examined for any *Prionus* larvae that had been dislodged during the process of tree extraction. The sapwood on all roots was examined for the presence of *Prionus* feeding injury and larvae (see photos in *.ppt file). Where deeper burrows were discovered in roots or in the crown, a chainsaw, handsaw, or ax was used to further examine the wood. The crown was defined in this trial as the very lowest part of the trunk from which all roots emanate. The sampled region of the crown was a 10-12 inch "band" of sapwood around the crown as well as a thorough probing of the underside, which often necessitated sawing off all roots. When burrows were found deeper within the crown, the trunk was sawed off with a chainsaw to provide top-down access to the larvae within. All *Prionus* larvae found during sampling were categorized and recorded as small (0.5-0.75 inch: first and second instars), medium (1-2 inches: third and fourth instars), or large (2.5-4 inches: fifth and sixth instars), and these age-based categories (see photos in *.ppt file) were distributed across three spatial zones for each tree: crown, roots, and loose soil.

Results and Discussion

Every sampled tree contained live *Prionus* larvae. A total of 131 *Prionus* larvae were found, and the average number of larvae per tree was 16.37 ± 4.47 (N = 8). No dead larvae were found, and neither live nor dead pupae were found. Waiting eight weeks between the treatment and sampling dates helped to ensure that the larvae had sufficient time to get a dose of the insecticide, but this duration also may explain why no dead or rotting larvae were found. Evidence of mortality (dead and/or dying larvae) caused by the insecticide (or by other means) may be difficult to discern because the rate of decay in irrigated soil is likely to be very high in mid-summer.

Efficacy of Admire insecticide. Among the Admire-treated trees, the average number of larvae was 18.50 ± 4.29 (N = 4) and ranged from seven to 26 larvae/tree (Table 1). Among the control trees, the average number of larvae was 14.25 ± 9.08 (N = 4) and ranged from two to 41 larvae/tree (Table 2). The difference in the number of *Prionus* found in treated trees versus untreated trees was not significant (LSD; $P > 0.05$). Tree-to-tree variability in larval numbers was quite high (Tables 1 and 2), which suggests that a much larger number of trees would need to be sampled to determine any possible differences between the treatments.

As shown in Figure 2, there were no significant differences between the Admire-treated trees and the untreated trees for each tree zone (roots, crown, and loose soil). Figure 2 appears to suggest that the Admire-treated trees had higher larval counts than those of the untreated trees, but the standard error associated with each mean was quite high, and therefore, it must be assumed the means were not different. More importantly, it appears that the Admire insecticide did not cause significant mortality among the *Prionus* larvae in the treated trees.

A closer examination of the insecticide effects within the root zone suggests that fewer of the young larvae (1st- and 2nd-instars) were found within the Admire-treated roots than in the roots of control trees (Fig. 3). This difference is not statistically significant, but given the greater larval abundance in the Admire-treated trees, the relatively small number of 1st- and 2nd-instars found within the roots of these trees is worth noting. It would be premature to conclude that the Admire treatments were the main cause of this observation; however, this trend may indicate some measure of insecticide efficacy in which the imidacloprid is taken up by young, healthy (and newly infested) roots and effectively delivered to the small *Prionus* larvae feeding upon them. Small larvae, presumably, would not cause rapid root mortality if the tree is healthy. Older and heavily infested roots were observed to be dead or dying in the more distal portions (smaller-diameters) of the root system (see photos in *.ppt file).

Comparisons of mean abundance of medium-sized larvae (Fig. 4) and large larvae (Fig. 5) showed no significant differences between treated and untreated trees. It was anticipated that there would be stark differences between treated and untreated trees and that the trends would be discernable with a relatively small sample size. It appears there was no effect of Admire on the *Prionus* larvae present within the mature cherry trees used for this trial, and future efficacy trials will likely require the destruction of many more trees to accommodate the high degree of between-tree variability. When applied as a soil-soak, imidacloprid may need to be applied on multiple occasions (perhaps once per month for 2 months) during the growing season, and the highest rate might need to be used to accommodate large soil volumes surrounding the larger trees. The active ingredient per tree is likely to be highly diluted when soaked into the soil of older trees. The reason for this is that the soil volume increases approximately by the *cube* of incremental changes to the radius of the soil volume. As a tree ages, the soil volume that its roots occupy will increase exponentially which likely has implications for any soil-applied systemic insecticide.

Spatial- and age-distribution of Prionus larvae. The spatial- and age-specific distributions of the *Prionus* larvae were analyzed only within untreated trees because these trees would be likely to present the most “natural” settings. In these trees, the greatest proportion of young larvae was found in the roots rather than the crown and soil (Fig. 6). The oldest larvae were more abundant in the crown than in the roots or soil (Fig. 7). It is worth noting that the older, larger larvae were much more prevalent in the loose soil than the younger larvae (Figs. 2-4) which may be the result of the older larvae seeking pupation sites outside of the tree tissues.

It appears that as the *Prionus* larvae feed, they spiral up the root (see photos in *.ppt file), moving inward toward the tree’s crown. Confining the analysis to the roots indicated that most of the time, the larvae present were small or medium-sized (Fig. 8). Looking only at the crown, most of the larvae present were the larger, older individuals (Fig. 9). Young larvae were still found feeding at the crown, but it appears that most of the young larvae first infest the root zone. As they feed, they increase in size and presumably move up the same root (see photos in *.ppt file) which would provide them with more root tissue on which to feed and in the process, bring them closer to the crown. In general, the largest

larvae were found on the largest roots (and in the crown). It was rare that a large larva was found on or in a smaller-diameter root. The small and medium-sized larvae predominated on the smaller roots but could be found feeding on the larger roots and the crown, as well.

The portion of the roots on which the larvae had already fed were dead and in various stages of decay (see photos in *.ppt file). If the conductive tissues of a root are dying, diseased, and/or decaying "behind" a larva as it approaches the crown, it stands to reason that the larva might not get a dose of the insecticide because the distal portions of the root's vascular system had been effectively destroyed. While this is just a hypothesis, further examination of the effects of Admire on *Prionus* larvae might benefit from the use of less infested trees. Another possible explanation for the reduced efficacy of Admire within this trial is that the sandy soil and frequent irrigation events caused the active ingredient to percolate out of the root zone before significant quantities were absorbed by the roots. To avoid this scenario, post-harvest applications (mid- to late-summer) could be made which should allow for greater ai concentrations within the soil profile because the trees are generally irrigated less after the crop has been harvested. Late-summer treatments would also target all *Prionus* generations (current-year eggs would have already hatched). Perhaps higher doses are needed, as well, particularly on trees with large canopies.
Accommodating these particular factors should provide greater resolution as to whether Admire can successfully control *Prionus* and other root-feeding pests.

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Figure 1. Five-acre sweet cherry block at Pettingill Farms (Willard, UT). The lighter shading along the borders represents the two replicates, and each letter ("T" = treated tree, "C" = control tree) represents the approximate position of a sampled tree.

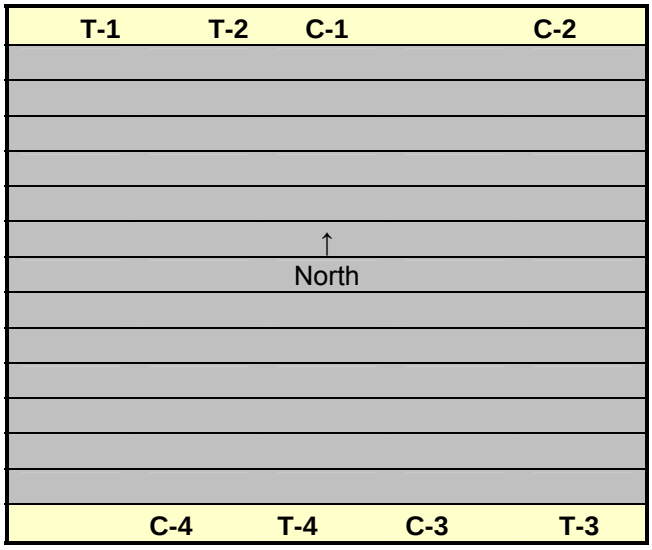

Table 1. Larval *Prionus* counts in the roots, crown, and loose soil around sweet cherry trees treated with Admire (24 fl oz/acre). T-1, T-2, T-3, and T-4 denote the four treated trees.

Tree	Larval Size	Roots	Crown	Soil	Total
1	Small	2	0	0	2
	Medium	0	3	0	3
	Large	2	0	0	2
	T-1 Total	**4**	**3**	**0**	**7**
2	Small	1	0	0	1
	Medium	7	2	0	9
	Large	5	2	0	7
	T-2 Total	**13**	**4**	**0**	**17**
3	Small	0	0	1	1
	Medium	6	4	0	10
	Large	2	6	5	13
	T-3 Total	**8**	**10**	**6**	**24**
4	Small	2	1	0	3
	Medium	3	2	1	6
	Large	6	6	5	17
	T-4 Total	**11**	**9**	**6**	**26**
All		**36**	**26**	**12**	**74**

Table 2. Larval *Prionus* counts in the roots, crown, and loose soil around untreated sweet cherry trees. C-1, C-2, C-3, and C-4 denote the four control trees.

Tree	Larval Size	Roots	Crown	Soil	Total
1	Small	1	0	0	1
	Medium	0	2	0	2
	Large	0	1	0	1
	C-1 Total	**1**	**3**	**0**	**4**
2	Small	8	4	0	12
	Medium	8	0	4	12
	Large	7	7	3	17
	C-2 Total	**23**	**11**	**7**	**41**
3	Small	0	0	0	0
	Medium	1	0	0	1
	Large	0	0	1	1
	C-3 Total	**1**	**0**	**1**	**2**
4	Small	1	1	0	2
	Medium	2	0	0	2
	Large	1	2	3	6
	C-4 Total	**4**	**3**	**3**	**10**
All		**29**	**17**	**11**	**57**

Figure 2. Comparison of larval densities between trees treated with Admire and untreated controls. Spatial distributions of larvae are divided into three zones (roots, crown, and loose soil). Within each zone, no statistically significant differences were found between controls and treated trees (LSD, $P > 0.05$).

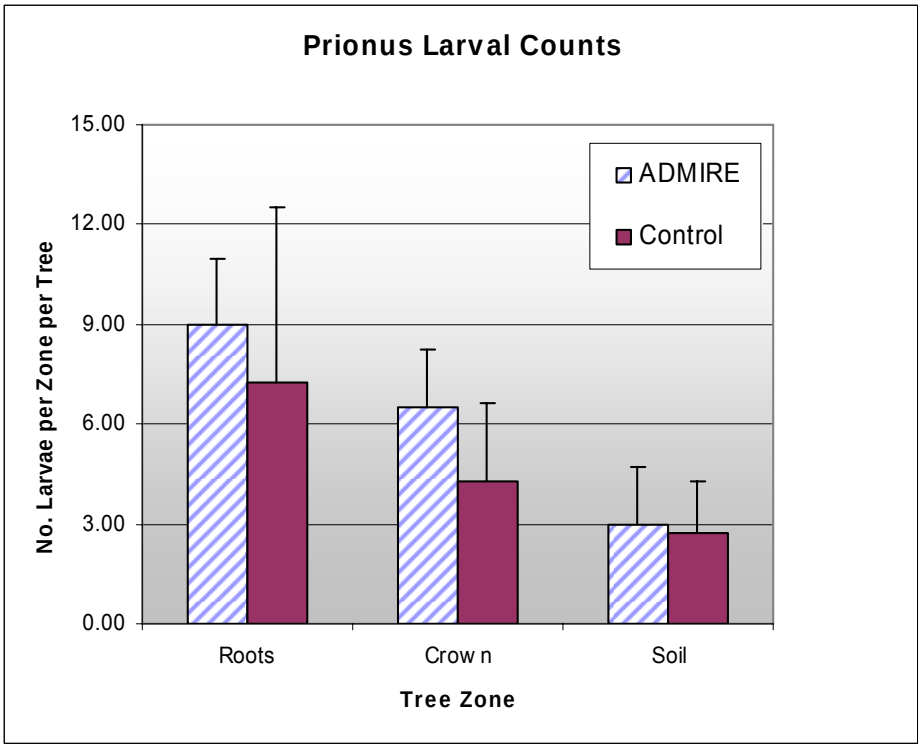

Figure 3. Comparison of small *Prionus* (1^{st}- and 2^{nd}-instars) densities between trees treated with Admire and untreated controls. Spatial distributions of larvae are divided into three zones (roots, crown, and loose soil). Within each zone, no statistically significant differences were found between controls and treated trees (LSD, $P > 0.05$).

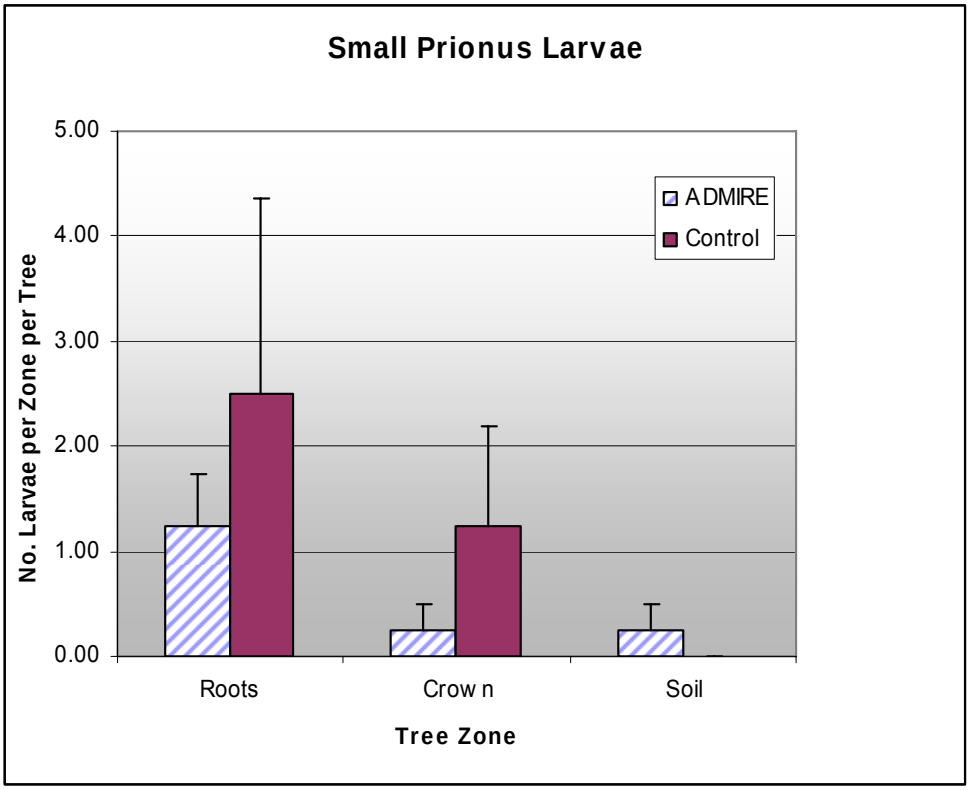

Figure 4. Comparison of medium-sized *Prionus* (3rd- and 4th-instars) densities between trees treated with Admire and untreated controls. Spatial distributions of larvae are divided into three zones (roots, crown, and loose soil). Within each zone, no statistically significant differences were found between controls and treated trees (LSD, $P > 0.05$).

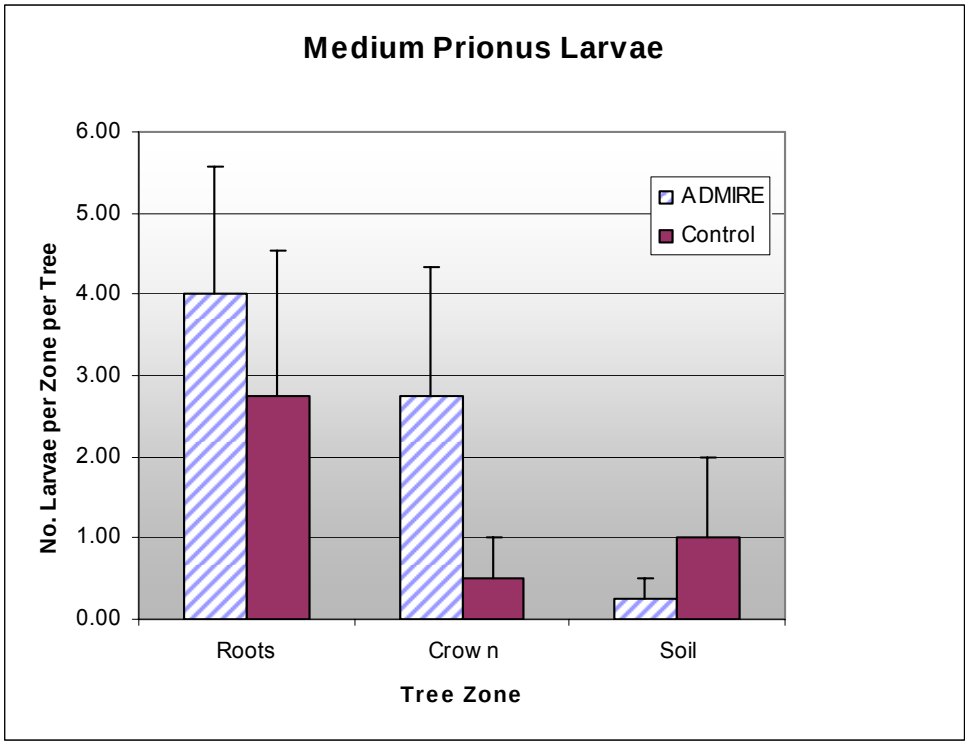

Figure 5. Comparison of large-sized *Prionus* (5^{th}- and 6^{th}-instars) densities between trees treated with Admire and untreated controls. Spatial distributions of larvae are divided into three zones (roots, crown, and loose soil). Within each zone, no statistically significant differences were found between controls and treated trees (LSD, $P > 0.05$).

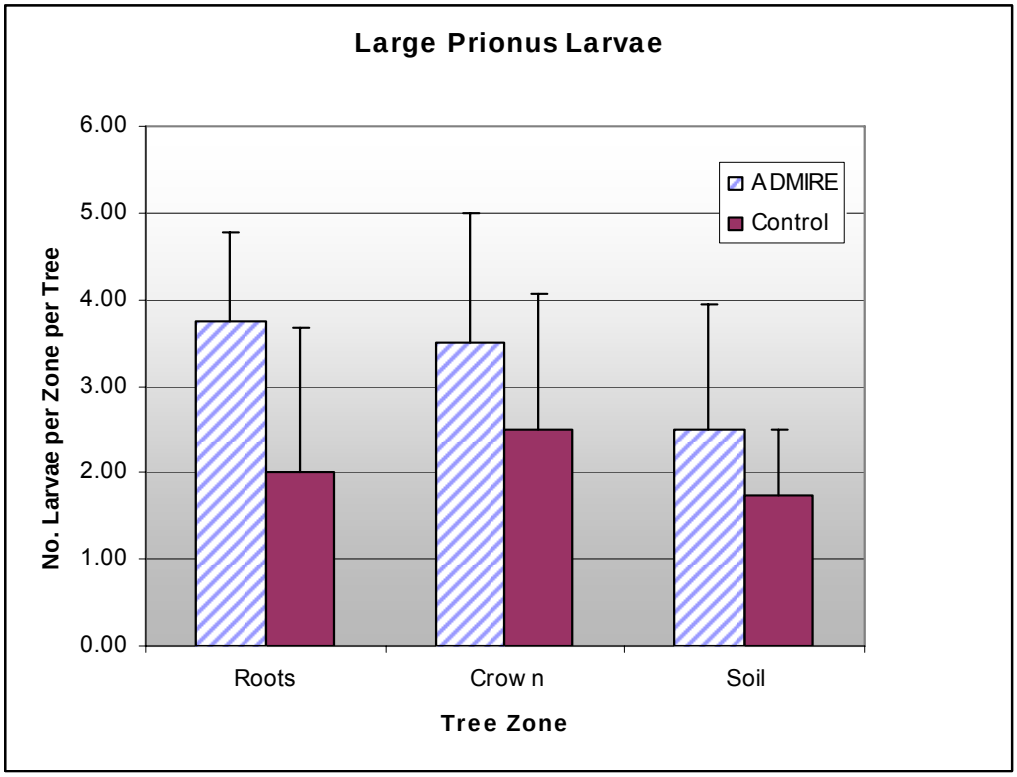

Figure 6. Distribution of younger larvae (1st- through 4th –instars) found within the roots, crown, and surrounding soil of untreated trees.

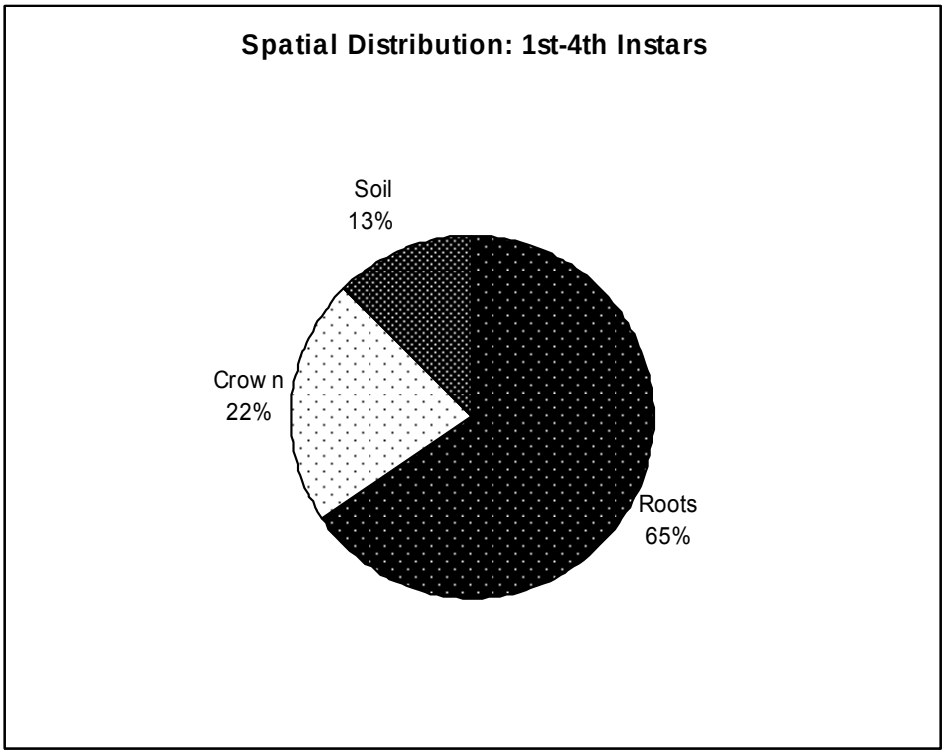

Figure 7. Distribution of older larvae (5^{th}- and 6^{th}-instars) found within the roots, crown, and surrounding soil of untreated trees.

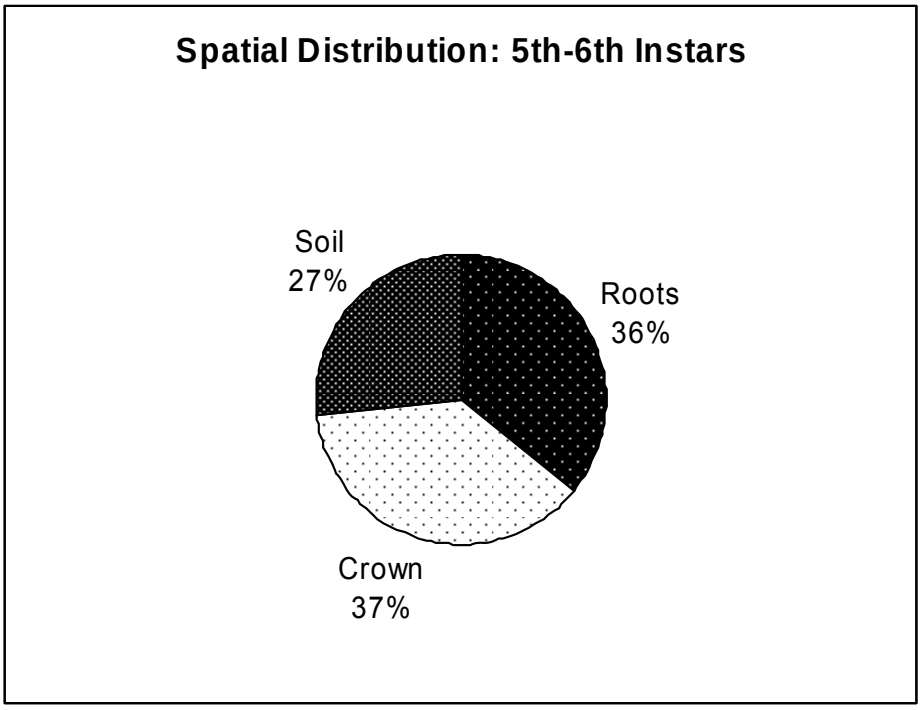

Figure 8. Age-distribution of *Prionus* larvae within the roots of untreated trees.

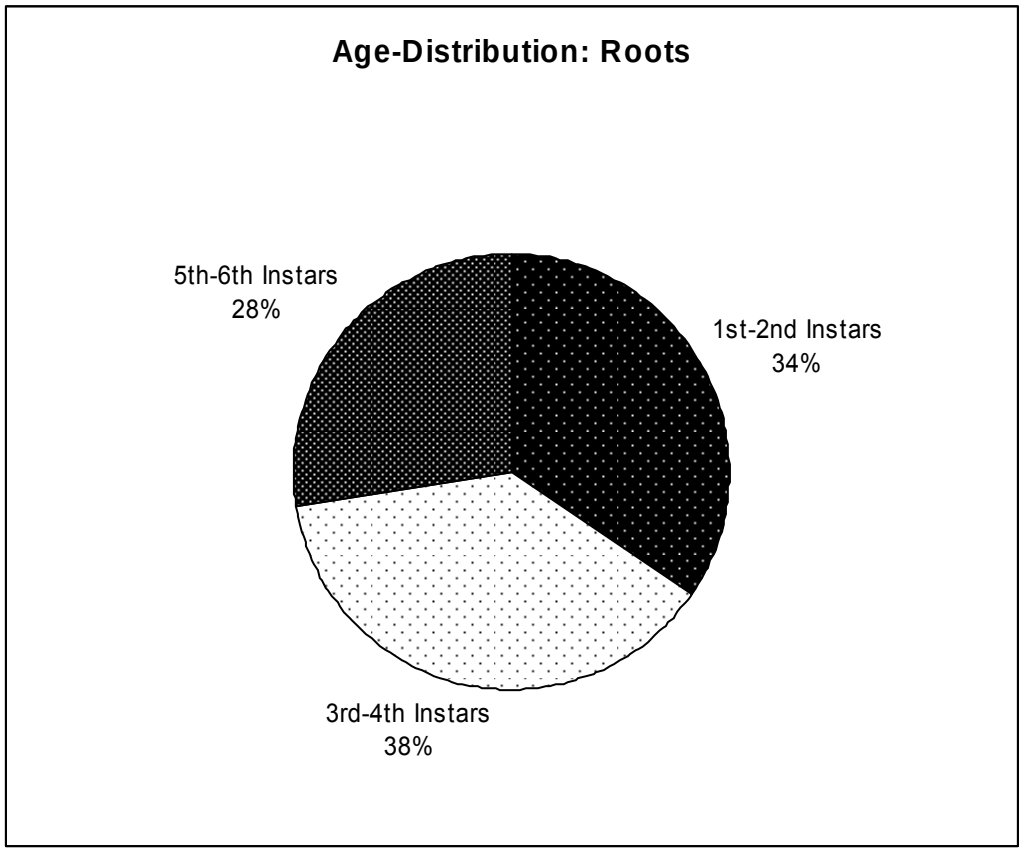

Figure 9. Age-distribution of *Prionus* larvae within the crown of untreated trees.