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Drift and Worker Exposure Resulting from Two Methods of Applying Insecticides to Pine Bark*

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The most common method of protecting pines from attack by bark beetles such as the western pine beetle, *Dendroctonus brevicomis* LeConte, is to saturate the bark on the bole of the tree with an insecticide spray. The sprays are usually applied from the ground with a hydraulic sprayer at high pressure (*ca.* 30-40 kg/cm^2). Use of high-pressure sprayers, however, can result in substantial contamination of both the worker and the area immediately surrounding the tree as a result of drift, splash, runoff, fallout, and simply missing the target. But the method of application is efficient in that the insecticide can be applied to many trees very quickly. Another method, which uses low-pressure home-and-garden tanks connected to a spray nozzle on a telescoping pole, has been tried (GIBSON 1977, HALL et al. 1982). We felt that much less environmental contamination would result from this method because the spray nozzle is never more than a few decimeters from the surface of the bole, and the lower nozzle pressure, therefore, provides less splash. Because some locations may be treated annually at times of high beetle populations, it would be beneficial to choose an application method which would result in the least amount of environmental contamination and worker exposure, and still be reasonably efficient.

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This paper reports the results of an experiment to compare the quantity of insecticide impinging on the worker who applies it and on the soil surface as a result of treating trees with (a) a high-pressure hydraulic sprayer from ground-level, or (b) a low-pressure home-and-garden tank connected to a telescoping pole.

METHODS

Study area

The insecticide was applied and deposits collected at the Forest Service's Institute of Forest Genetics, in Placerville, California. The site, at approximately 825 m in elevation, is an arboretum that is relatively flat, with evenly-spaced ponderosa pines, *Pinus ponderosa* Dougl. ex Laws, of approximately 30-50 cm diameter-at-breast-height (DBH). The soil is covered with sparse forbs and pine duff, with little or no brush.

Application of insecticides

A 1.0% carbaryl (Sevimol^R) spray with 0.1% Rhodamine B dye added (for deposit assessment) was applied to individual trees with either a Maruyama^R power sprayer (Model MS253-ECR) at 30 kg/cm^2 or a Hudson^R stirrup garden pump at 2.8 kg/cm^2 connected to a telescoping pole (HALL et al. 1982). Five workers applied the 1% carbaryl spray to two trees with each of the two sprayers, each worker treating four trees. The insecticide was applied over the entire bole of the tree to a height of *ca*. 10.5 m. The spray was applied to the point of runoff, *ca*. 1.0 L/m^2, or *ca*. 8.0 L/tree.

Trees were sprayed in August, 1981 in the morning from 1 h past sunrise to *ca*. 1100. Ambient air temperature never exceeded 25° C. Trees were not sprayed if windspeed at the ground exceeded *ca*. 10 kph. The bole of the tree was usually treated in three swaths with either method of application. In all instances, to avoid being directly in the line of the drift, the workers were careful not to apply the insecticide directly into the wind. They stood 3 to 5 m from the base of the tree for each method of application.

Each worker wore a hard hat and face shield, a respirator, rubber gloves, boots, and waterproof coveralls. Operational applications would probably be made with similar protective clothing, however, waterproof coveralls are not required. Clean cotton coveralls (which are absorbent) are usually supplied to workers.

Collection of spray fallout and drift

Spray fallout and drift were collected in 150 x 15-mm plastic petri dishes, placed on the ground, at eight points of the compass at 1, 3, 5, 8, and 12 m from the edge of the tree bole. After the insecticide was applied to each tree, each of the eight petri dishes for each of the five distances was rinsed once with 30 ml 95% ethanol and then with 20 ml 95% ethanol. The sixteen rinses for a given distance were combined. Two 20-ml aliquots were then taken and stored in the dark at room temperature for 4 days until the amount of insecticide could be quantified.

Insecticide deposited on the workers was collected on 14.5-cm^2 pieces of Whatman Chromatography paper (grade 3 MM) taped to the worker. Two pieces were placed with masking tape in these locations: sides of face, sides of neck, chest, back, forearms, thighs, and lower legs. After each tree was sprayed, the squares of paper were collected and individually placed in vials with 20 ml 95% ethanol, then stored in the dark at room temperature for 4 days.

Quantification of insecticide deposit

The amount of insecticide was determined by analyzing the concentration of dye in the 20-ml aliquot of ethanol with an Aminco-Bowman spectrophotofluorometer (American Instrument Company) and converted to $\mu g/cm^2$ of soil or body surface. The total amount of exposure to the worker was determined by the body surface area calculations of DAVIS (1980). Recovery of the dye from the paper pieces was tested under similar conditions: mean recovery of 10 samples was 105.8% (S.D. = 4.1%).

Experimental design and data analysis

The experiment was done as a randomized complete-block design with two treatments (application techniques), five blocks (workers), and two replications. All treatment x block x replication combinations were randomly assigned to 20 trees. The order in which treatments were applied was also random. The response variables were μg of carbaryl/cm^2 for each of five distances on the ground, and for all body regions, and mg of carbaryl for total body exposure.

Differences between application techniques in insecticide deposit on the ground at all distances from the tree bole was determined by Hotelling's T^2 statistic ($p = 0.05$). Difference between the two application techniques in the total insecticide exposure of the worker, the deposit of carbaryl at individual distances from the tree, and the deposit on various body regions was determined with a t-test ($p = 0.05$).

RESULTS AND DISCUSSION

Soil surface deposits of the insecticide spray did not differ significantly between application methods at any distance from the tree (Table 1). More than 80% of the insecticide applied stayed on the trees. With an average of 8 L insecticide spray applied to each tree, 18.1% of the solution (or 13.8 g of carbaryl) fell to the soil as a result of using the high pressure sprayer. The corresponding figure for the telescoping pole was 17.5% (13.3 g carbaryl). Insecticide deposit was greatest at 1 m from the tree and was nearly undetectable at 12 m. In fact, ca. 45% of the insecticide that fell to the ground fell within 2 m of the base of the tree.

Table 1. Amount of carbaryl deposited ($\mu g/cm^2$) on the ground at various distances from the tree bole with two methods of application.[1]

Distance from tree (m)	Method of application	
	Pole	Hydraulic
1	47.4 (19.1)	50.2 (17.0)
3	11.9 (5.9)	14.4 (4.0)
5	2.9 (2.3)	2.3 (1.5)
8	0.4 (0.7)	0.3 (0.3)
12	0.1 (0.1)	0.0 (0.1)

1/ Mean (standard deviation) of 10 observations. None of the values is significantly different from the other at $p = 0.05$ at any distance from the tree bole as determined with Hotelling's T^2 statistic.

Insecticide deposit on the workers resulting from the two application techniques differed significantly ($p < 0.01$) even though there were dramatic differences between replications and workers with either technique (Table 2). Two major factors con-

Table 2. Total body exposure of each worker (in mg of carbaryl).

Worker	mg carbaryl[1/]			
	Pole		Hydraulic	
	rep 1	rep 2	rep 1	rep 2
1	18.4	104.2	0.03	0.64
2	110.0	8.1	1.6	0.10
3	8.4	12.4	0.05	10.3
4	67.4	190.5	0.13	0.76
5	89.6	17.6	0.29	0.78
Average (S.D.)	62.7 (61.0)		1.5 (3.2)	

1/ Difference between treatments is significant at $p = 0.01$.

tributed to this variability: windspeed and the number of limbs on the lower bole of the tree. The wind tended to increase in velocity from sunup until late morning. Naturally, with greater wind velocity, the spray stream breaks up more and the insecticide drift is carried farther. With more limbs on the bole or a lower tree crown, more insecticide is deflected and does not reach the bole. Furthermore, with the telescoping pole, the nozzle needs to be weaved in and out of the branches and results in much more insecticide spray entirely missing the bole and more time spent applying the insecticide.

Use of the telescoping pole resulted in a mean value of 62.7 mg insecticide deposited on the worker whereas the high-pressure hydraulic sprayer resulted in an average of only 1.5 mg deposited. With the hydraulic sprayer most of the deposit was on the arms and thighs. With the telescoping pole, most of the insecticide was deposited on the chest, arms, and legs (Table 3). Some of this deposited insecticide was, in our opinion, the result of direct contact with a contaminated pole and lines. Much less direct contamination was apparent with the high-pressure hydraulic sprayer.

The results of this test were surprising in one major respect: the ground-level contamination that resulted from each application method was almost identical. Through our experience (HALL et al. 1982) with both methods, we suspected that use of the telescoping pole would result in much less insecticide falling to the ground than that from use of the high-pressure, ground

Table 3. Surface area of body regions and amount of carbaryl impinging on each region resulting from two methods of application.

Body region potentially exposed to pesticide	Surface area[1/] of body region (cm^2)	Carbaryl impinging[2/] on body ($\mu g/cm^2$)	
		Pole	Hydraulic
Face	650	0.14(0.23)	0.04(0.08)
Neck	260	1.24(3.19)	0.06(0.15)
Chest and abdomen	3550	4.94(5.52)*	0.08(0.13)*
Back	3550	0.13(0.18)	0.02(0.06)
Arms	2530	7.00(9.65)*	0.21(0.62)*
Thighs	2250	4.99(4.45)**	0.15(0.29)**
Lower legs	2380	6.40(8.00)*	0.08(0.11)*

1/ Surface area values calculated by DAVIS (1980).

2/ Means of 10 observations (standard deviation) in a row followed by * or ** are significantly different at p = 0.05 or 0.01 level, respectively.

sprayer. The latter appeared to be dispersing more insecticide off-target but the applications (< 30 sec/tree) were compared with applications made with the telescoping pole (2 to 10 min/ tree). Rapid applications also are likely to result in much less inhalation of spray droplets by workers.

The difference in worker exposure resulting from the two application techniques was not surprising but the magnitude of the difference was. Assuming that the average worker weighs 65 kg, and given that the acute dermal LD_{50} for mammals is 2000 mg/kg, a worker would receive 0.05% of an acute dermal LD_{50} for each tree treated with the telescoping pole and 0.001% of an acute dermal LD_{50} dose for each tree treated with the high-pressure hydraulic spray. In our field research, each worker can treat 20 to 30 trees in 1 day (HALL et al. 1982). We could probably increase the number of trees treated to 100 to 150 if we did not need to travel at least 0.5 km between trees. Treating 150 trees would result in a worker receiving 7.5% of the acute dermal LD_{50} with the telescoping pole, and 0.15% of the acute dermal LD_{50} with the high-pressure hydraulic sprayer. However, almost all of the insecticide spray impinging on the worker would not reach the skin if proper protective clothes and equipment are worn. Given equivalent environmental contamination, much shorter application time, and significantly less worker contamination, we suggest that for research purposes and operational programs, the telescoping pole with low-pressure sprays be discarded in favor of ground applications with high-pressure hydraulic sprays.

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