Journal of the American Mosquito Control Association, 12(2):325–328, 1996

DISPERSAL OF 10–14-MESH CORNCOB GRANULES IN STACKED TIRES

JOEL P. SIEGEL,[1] ROGER CIESLIK,[2] JACK THENNISCH,[3] LYLE CLARKE, JR.[3] AND ROBERT J. NOVAK[1]

ABSTRACT. Dispersal of 10–14-mesh corncob granules was evaluated in 2 random-stacked tire piles, one shingle-stacked tire pile, and one column-stacked tire pile located in a used-tire storage facility in Chicago, IL. Ninety percent and 98%, respectively, of the tires in the 2 random-stacked piles contained granules. In the shingle-stacked tire pile 87% of the tires sampled contained granules, and the number of granules per tire was dependent on depth. The 2 bottom rows of tires were 73.9% less likely to contain granules than the 5 rows above them. In the column-stacked tire pile 91.2% of the tires contained granules and the relationship between granule recovery and tire depth was logarithmic. Overall, the dispersal of 10–14-mesh corncob granules was comparable to that of 8-mesh corncob granules evaluated in a previous study at this site.

Waste tires can serve as a larval habitat for a variety of mosquitoes of medical importance. The Rubber Manufacturers Association in Washington, DC, estimated that 200 million tires are added yearly to the solid waste stream in the United States (Novak et al. 1990). Controlling mosquitoes that utilize waste tires as a larval habitat is complicated by the various methods used to stack tires. Shingle-stacked tires, where each tire within a horizontal row overlaps its neighbor, as well as column-stacked tires are particularly difficult to treat because the tire openings may be partially obstructed. Novak et al. (1985) evaluated the suitability of both 4–8-mesh corncob granules as carriers for temephos and 12–14-mesh corncob granules as carriers for *Bacillus thuringiensis* serovar *israelensis* (*B.t.i.*) and concluded that larvicides formulated on corncob granules should be suitable for tires. Subsequently, Novak et al. (1990) evaluated the dispersal of blank 8-mesh corncob granules applied by a mobile elevated platform (cherry picker) in waste tires and reported penetration levels of 85% in column-stacked tires, 93% in random-stacked tires, and 95% in shingle-stacked tires (penetration in the context of this paper refers to the delivery of granules to the portion of the tire that holds water). The purpose of this study was to determine if the dispersal or penetration ability of 10–14-mesh corncob granules in tires stacked in random, shingle, and column piles is comparable to that of the larger 8-mesh granules. Additionally, we were interested in estimating the percentage of the corncob granules that actually penetrated the target tires.

This study was carried out in late June 1995 in the same tire yard studied by Novak et al. (1990), located in Chicago, IL. There were 105,000 tires in the yard and these tires were treated (124,740 g of 10–14-mesh corncob granules formulated with temephos) by Clarke Outdoor Spray Co. (Roselle, IL) 3 days before our study. The granules were applied using an Echo-DM9 backpack sprayer (Echo, Inc., Lake Zurich, IL). The amount of larvicide used was based on the personal experience that applicators from Clarke Outdoor Spray Co. had with this tire yard and corresponded to 1.188 g per tire (124,740 g ÷ 105,000 tires). Based on weights determined in the laboratory, 1.188 g is equivalent to an average of 419 granules. Two random-stacked (random in this study means that the tires were not ordered) car tire piles within the yard were used in this study. The first tire pile was 2.44 m high, and 2 perpendicular transects (AOD and COB, intersecting at O, resulting in half transects OA, OD, OB, and OC) were run through the pile (Fig. 1). Transect OD was perpendicular to a security fence. Fifty tires along the transects were sampled in this pile. Positional information (on the ground at the perimeter, top of pile, middle of pile, and bottom of pile) was recorded and the granules inside each tire were either counted on site or removed and placed in numbered bags and counted in the laboratory. This procedure was followed for all tire piles. None of these tires contained water. The second tire pile, 2.74 m high, contained approximately 2,000 tires arranged in concentric circles. A single transect was laid to the center of the pile and 50 tires along this transect were examined. All tires contained water. A single, shingle-stacked tire pile, 5.18 × 4.42 × 2.74 m (L × W × H), containing approximately 350 tires was chosen for study. The tires were ar-

[1] Illinois Natural History Survey, Center for Economic Entomology, 607 East Peabody Drive, Champaign, IL 61820.

[2] City of Chicago, Department of Health, 2160 West Ogden Street, Chicago, IL 60612.

[3] Clarke Outdoor Spray Co., P. O. Box 288, Roselle, IL 60172.

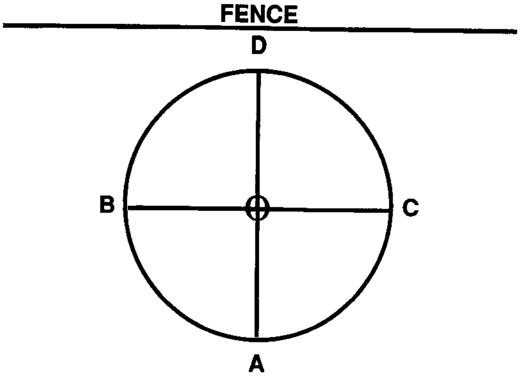

Fig. 1. Schematic of the transects run through the first random-stacked tire pile.

ranged in 3 horizontal rows (row A closest to the interior of the yard and row C adjacent to a riverbank), stacked 7 tires high (7 vertical rows); the top vertical row was designated row 1. Every third tire was examined in this pile for a total of 115 tires, and positional data were recorded. Fifty-three tires contained water.

An additional study was conducted on 36 truck tires, stacked 6 rows high (top tire designated as row 1), 2 columns abreast, and 3 columns deep located in a fenced lot adjacent to the tire yard. The interior opening of the tires was 1.1 m and these tires received 5,680 g of blank 10–14-mesh corncob granules applied by an Echo-DM9 backpack sprayer. This treatment corresponded to 157.778 g per tire (55,752 granules). These tires were examined 24 h after treatment. All tires contained mud and rubble. Tire contents were removed in numbered bags and the granules counted in the laboratory.

Linear regression, 2-way analysis of variance (ANOVA), unpaired Student's t-test, and Mann–Whitney U-tests were conducted using 2 personal computer software packages (Statview, Abacus Concepts, Berkely, CA, and JMP, SAS Institute, Cary, NC) to evaluate differences in granule penetration within the tire piles. For the data collected from the shingle-stacked tire pile, 2 × 2 contingency tables were used to calculate odds ratios according to Kelsey et al. (1986). We weighed 300 individual 10–14-mesh corncob granule blanks, 100 individual 8-mesh corncob granule blanks, and 1,920 10–14-mesh corncob granules formulated with Vectolex® (Abbott Laboratories, North Chicago, IL) using a Mettler AE 240 electronic balance with a readability of 0.01 mg (Mettler Instruments, Hightstown, NJ). This information was used to estimate the percentage of granules that actually reached the target as well as to determine the weight ratio of 10–14-mesh granules to 8-mesh granules.

In the first random-stacked tire pile, 90% of the tires contained granules. There was no difference in the number of granules recovered from tires located on the perimeter or interior of the pile ($t = -0.31$, df = 48, $P = 0.76$) or in tires located in the top, middle, or bottom of the tire pile (F = 0.780, df = 49, $P = 0.46$). The mean number of granules per tire ± SD is reported in Table 1. When the pattern of dispersal was elevated along the transects, tires collected from transect OD contained significantly fewer granules than tires sampled from transects OA, OB, and OC (F = 6.79, df = 49, $P < 0.001$). Mean granules per tire ± SD for transects OA, OB, OC, and OD were 293.5 ± 236.8, 372.5 ± 202.8, 151.7 ± 164.3, and 5.7 ± 8.4, respectively.

In the second random-stacked tire pile, 98% of the tires contained granules. There was no difference in the number of granules recovered from tires located on the perimeter or interior of the pile ($t = -0.74$, df = 48, $P = 0.48$). Tires sampled in the middle contained almost twice as many granules than the tires above and below them (Table 1) ($Z = -2.90$, $P = 0.004$). Additionally, the number of granules recovered from tires increased significantly in a linear fashion as we approached the center of the tire pile, $y = 11.159 + 11.934x$, $r^2 = 0.12$, $P = 0.019$, where y is the number of granules/tire, and x is the row number (1 is the outer row and row 7 is the center of the tire pile).

In the shingle-stacked tire pile, 87% of the tires contained granules. There was no difference in the number of granules recovered from tires located on the perimeter or interior of the pile ($t = 0.86$, df = 113, $P = 0.39$). There was a significant difference in the dispersal of granules between the 3 horizontal rows (F = 9.15, df = 114, $P < 0.001$). Rows A, B, and C contained 55.5 ± 86.1, 21.6 ± 24.9, and 6.2 ± 9.3

Table 1. Mean number of granules per tire ± SD for 2 random-stacked tire piles. Top, middle, and bottom refer to the interior of the pile. Fifty tires were sampled from each pile.

Pile	Perimeter	Top	Middle	Bottom
1	203.1 ± 174.4	249.5 ± 247.8	269.2 ± 273.5	150.3 ± 167.6
2	34 ± 28.0	49.1 ± 101.0	81.2 ± 52.0	43.6 ± 32.8

granules per tire, respectively. Granule penetration was a function of tire depth and could be described by the formula $y = -1.454x + 1.94$, $r^2 = 0.212$, $P < 0.001$ (where y is the logarithm of [1 + number of granules per tire] and x is the logarithm of [1 + row number]). According to this formula, there was a 45% drop in the number of granules recovered from tires in vertical row 2 compared to vertical row 1, and tires located in the bottom row had 90% fewer granules than tires located on the top of the pile. Tires located in the bottom 2 vertical rows were 73.9% more likely to lack granules than tires located in the 5 vertical rows above them (odds ratio = 0.26, $\chi^2 = 7.73$, $0.01 > P > 0.005$). Tires in these same 2 bottom vertical rows were 3.41 times more likely to contain water than tires located in the 5 vertical rows above them (odds ratio = 3.41, $\chi^2 = 6.86$, $0.01 > P > 0.005$).

Thirty-four truck tires out of the 36 treated were successfully sampled in the study, and 91.2% of these tires contained granules. Two tires located on the top left side of the pile could not be sampled because they contained too much rubble. Consequently, we could not compare differences in dispersal between the columns on the left and right side of the pile. The relationship between the number of granules per tire and row within a column was logarithmic and could be described by the equation $y = -14{,}907.877x + 11{,}731.478$, $r^2 = 0.66$, $P < 0.001$ (where y is the number of granules per tire, x is the logarithm of [1 + row]). According to this regression, there was a 36% drop in the mean number of granules per tire between rows 1 and 2, and a 98% drop in the mean number of granules per tire between rows 1 and 5. The regression equation predicts that there should be no granules in the bottom row, but we observed a mean of 654 granules per tire on the bottom compared to a mean of 9,719 granules per tire in row 1. This discrepancy can be explained by the fact that all regressions are most accurate for the mean values of x and y and that the confidence belt becomes asymptotic at the extremes (Siegel et al. 1992). Consequently, there is greater uncertainty associated with the number of granules predicted in row 6.

The mean weight ($\pm$SD) of a blank 10–14-mesh corncob granule was 0.002441 $\pm$ 0.000781 g. The mean weight of a blank 8-mesh corncob granule was 0.016796 $\pm$ 0.007386 g. The weight ratio of 10–14-mesh granules to 8-mesh granules was 6.88. When we compared the weight of 10–14-mesh granules formulated with Vectolex to 10–14-mesh blanks, there was approximately a 16% gain in weight. The overall mean for granules per tire in the 2 random-stacked tire piles and the shingle-stacked tire pile was 79.76 $\pm$ 143.82 granules per tire. This corresponds to a mean dose of 0.195 g per tire, based on blank granule weight, or 0.226 g per tire adjusted upward for the added weight of the toxicant. Based on a mean dose per tire of 1.186 g (124,740 g $\div$ 105,000 tires), between 16.4% and 19% of the larvicide was actually delivered to the tires. In the column-tire pile, there was a mean of 2,396.38 $\pm$ 3,120.40 granules per tire, which would correspond to a mean dose of 5.850 g based on blank granule weight. Based on a mean dose per tire of 157.778 g (5,680 g $\div$ 36 tires) 3.7% of the blanks were delivered to the truck tires. We note that standard deviations greater than the mean resulted because some tires contained no granules.

The simplest explanation for the dispersal pattern of the granules in the single shingle-stacked and 2 random-stacked tire piles is that the applicator stood in one spot instead of applying the granules from several places along the perimeter. In the first random-stacked pile, access to transect OD was hindered by a security fence (Fig. 1). It seems likely that the applicator applied the granules from the opposite end of the transect (AO), and did not follow up the treatment by applying through the fence. Likewise, in the shingle-stacked pile, access to horizontal row C was hindered by the riverbank. Hence, the applicator probably stood in the interior of the tire yard; consequently, this farthest row received the lowest dose. The dispersal pattern in the second random-stacked pile, with an increasing dose per tire as the center was approached, suggests that the applicator stood at the opposite end of the pile from the side we sampled. Although coverage was excellent in the 2 random-stacked piles, we believe that a more even distribution of larvicide would have occurred if the application was made from 2 sides. The importance of applying larvicide from several spots is underscored by the data from the shingle-stacked pile. The majority of the tires that were missed were located in row C, and these same tires were more likely to hold water than the more accessible tires.

Direct comparisons are difficult to make between this study and the previous study by Novak et al. (1990). The previous study used 8-mesh granules and a cherry picker for application, and the granule size difference complicates our comparison of penetration. If we use the ratio of 10–14-mesh weight to 8-mesh weight (6.88), all tires containing less than 7 granules in this present study would be scored as empty. This would adjust our penetration levels to 90% and 86% for the first and second random-stacked piles, and 60.9% for the shingle-stacked pile. However, we do not know if this adjustment is appropriate, and 10–14-mesh granules may lodge in spaces that larger granules will not. If this is true, tires that would not receive larvicide if 8-mesh granules were used will contain toxicant when the smaller granules are employed. Our data suggest that the individual applying the larvicide has a greater impact on the success of an application than the size of the corncob granule, and that the most effective method would be to apply larvicide from several points on the perimeter of a tire pile, especially if treatment from above (cherry picker) is not feasible. We believe that column-stacked tires pose a unique challenge due to the drop in granule penetration between rows 1 and 6 (>98%). Consequently, it may be advisable to avoid stacking tires in columns greater than 6 rows tall in order to ensure successful treatment.

We thank Ben Buie, David Clark, Scott Hanson, David Kostner, Nina Krasavin, Richard Lampman, Hilary Lee, Karen McClellan, Jennifer Mehren, Evalina Ontiveros, and Larry Symczak for help in collecting and counting the granules. Our work was supported in part through the Illinois Waste Tire Act Grant SENR-TM-2 administered by the former Illinois Department of Energy and Natural Resources (currently the Illinois Department of Natural Resources) and by Abbott Laboratories.

REFERENCES CITED

Kelsey, J. L., W. D. Thompson and A. S. Evans. 1986. Methods in observational epidemiology. Oxford Univ. Press, Inc., New York, NY.

Novak, R. J., D. J. Gubler and D. Underwood. 1985. Evaluation of slow-release formulations of temephos (Abate®) and *Bacillus thuringiensis* var. *israelensis* for the control of *Aedes aegypti* in Puerto Rico. J. Am. Mosq. Control Assoc. 1:449–453.

Novak, R. J., B. A. Steinly, D. W. Webb, L. Haramis, J. Clarke, Jr., B. Farmer and R. Cieslik. 1990. Penetration rate of two pesticide carriers at a large used-tire storage facility in Chicago, Illinois. J. Am. Mosq. Control Assoc. 6:188–196.

Siegel, J. P., R. J. Novak, R. L. Lampman and B. A. Steinly. 1992. Statistical appraisal of the weight–wing length relationship of mosquitoes. J. Med. Entomol. 29:711–714.