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CONTROL OF *AEDES ALBOPICTUS* IN WASTE TIRE PILES WITH REDUCED RATES OF TEMEPHOS-TREATED GRANULES[1]

C. D. MORRIS,[2] D. A. DAME[3] AND J. W. ROBINSON[4]

ABSTRACT. Two days following treatment, larval populations of *Aedes albopictus* in waste tires treated with granular formulations of temephos were reduced 90% at the 0.11 kg AI/ha rate, 98% at the 0.56 kg AI/ha rate, and 100% at the 1.12, 11.21, and 22.42 kg AI/ha rates. Nearly 100% control was achieved for 8 wk at the 0.5 kg AI/ha rate, for 7 wk at the 1.12 kg AI/ha rate in one replicate, and for at least 5 months at the 11.21 and 22.42 kg AI/ha rates. These results indicate that prolonged control can be achieved with granular formulations at half (11.21 kg/ha) the maximum label rate and that excellent immediate control can be expected at 2.5% the maximum label rate.

INTRODUCTION

An increasingly vexing problem for mosquito control operations is the impact of *Aedes albopictus* (Skuse) in both urban and rural habitats. Many niches previously dominated by *Aedes aegypti* (Linn.) in Florida and elsewhere in the southeast have become dominated by *Ae. albopictus* (Hobbs et al. 1991, O'Meara et al. 1995). This aggressive mosquito now accounts for the majority of complaints from peridomestic situations in many mosquito control programs in the southeast such as those in Leon County, FL, the City of Gainesville, FL, and Chatham County, GA (W. Gene Baker, Kellie Etherson, and Oscar Fultz, unpublished data).

Waste tires are a well-known major breeding site of *Ae. albopictus*. This source of pestiferous and potentially disease-bearing mosquitoes (Scott et al. 1990, Mitchell et al. 1992) offers a focus for control that can be readily targeted by organized mosquito control operations. Elimination of waste tires is the preferred method to control tire-breeding mosquitoes; however, considerable manpower and expense is required, a factor that has lead to the increased use of chemical control measures.

Temephos (Abate®) is labeled for use on waste tire piles, and granules are perhaps the most extensively used formulation for control of mosquitoes resident in tires. The efficacy of temephos has been well documented (Novak et al. 1985, 1990; Beehler et al. 1991). Although up to 22.42 kg/ha of actual temephos can be applied to tire piles, the application of the maximum rate presents operational problems when applied as 5% or 1% granules because 181.4 and 907.2 kg of granular formulation per acre are required, respectively.

Thus, studies were conducted on alternative formulations and lower application rates. In 1993 we conducted trials on sand, corncob grit, aqueous, and ULV formulations of temephos applied to large tire piles in central Florida. Control levels in excess of 95% were observed in some of these preliminary efforts, but statistically significant differences were not achieved between formulations because of wide variations in larval density in untreated check plots (D. Dame, C. Morris, and J. Robinson, unpublished data). The trials, however, did reveal the ease of application of corncob grit formulations, which appeared to be as effective as any of the formulations tested. These results led to the tests with corncob grit formulations reported here.

MATERIALS AND METHODS

Studies were initiated in September 1994 at the site of several large waste tire piles located in Land O'Lakes, FL. The study site has been described by Morris and Robinson (1994) as having 7 north–south- and 2 east–west-oriented tire piles, each approximately 15 m wide, 3 m high, and 45–60 m long. In the current series of tests, 3 of the piles were each subdivided into 6 transverse sections. The interior 4 10-m sections received 0, 0.11, 0.56, 1.12, 11.21, or 22.42 kg/ha of temephos, applied at a rate of 0.45 kg of dry corncob grit granules per 9.3 m^2. One pile was treated each week with 3 of the interior sections receiving temephos granules and the 4th section receiving blank granules and serving as the untreated check. Each application rate was replicated twice during the series, except for the maximum label rate (22.42 kg/ha), which was not replicated.

The granules were formulated by spraying an aqueous solution of Abate 4E onto 5–8-mesh corncob grits tumbling inside a mixer. Agitation was continued until the resulting granules were

[1] This is University of Florida, Florida Agriculture Experiment Station Journal Series No. R-04944.

[2] Florida Medical Entomology Laboratory, University of Florida, 200 9th Street SE, Vero Beach, FL 32962.

[3] Entomological Services, 4729 Northwest 18th Place, Gainesville, FL 32605.

[4] Pasco County Mosquito Control District, 2308 Marathon Road, Odessa, FL 33556.

dry. Treatments were randomly assigned to sections. To minimize variation in the applications, the same experienced technician applied all the treatments. Granules (4.5 kg) were applied on the east side of the sector with a high-velocity granule blower (Echo Model DM-9), and then the operator repeated the process on the west side. Each weekly series was initiated on Sunday with a blank granule application on the untreated check sector. The remaining applications were conducted each subsequent Monday, Tuesday, and Wednesday with granules of increasingly higher levels of temephos during the week.

Two different sampling methods were used to assess the immediate impact on the target population. For the first method, the contents of 6 tires situated on the surface layer of the east side of the pile were vacuumed out 1 or 2 days before applications of granules and the larvae and pupae were separated by a sieve capable of retaining 2nd-instar and larger larvae and pupae, pipetted into cups, counted, and replaced. Two days posttreatment these tires were sampled again, in the same manner as the pretreatment samples, except that the contents were examined microscopically at 20×, to determine if immatures were alive or dead. The immatures were not returned to the tires. The results of the 2 samples were then compared to estimate percentage population reduction; data from the untreated checks were used to adjust the estimates with Abbott's formula (Abbott 1925) and calculate the level of control achieved.

The second method consisted of withdrawing the contents from 50 tires, also located on the east side of the pile between ground level and the top of the pile, 2 days posttreatment. The visible invertebrates were separated by sieve and pipette, placed in vials, and observed immediately for signs of intoxication. The first 6 tires of the 50 were the same tires used in the first evaluation. The mosquito larvae were counted and subsequently identified by microscopic examination. Samples were collected from tires as deep as 1.3 m in the pile, as previous observations had revealed larvae at these depths (Morris and Robinson 1994). The location and depth of all sampled tires were recorded; tires without water were excluded from the sampling. For the 50-tire sample, the level of control was determined by comparing larval numbers in the treated sectors with those in the untreated checks of the same week and in the same tire pile.

Pretreatment observations for a 10-tire sample, a longevity-of-effectiveness evaluation, were conducted 1–2 days prior to treatment. The contents were withdrawn from 10 preselected tires on the surface of the pile (from ground level to the top of the pile) that contained larvae. Larvae in these samples were separated by sieve and pipette, counted, and returned to the same tire. Similar replacement sampling was conducted 2 days posttreatment, then weekly, and finally monthly. In the 10-tire sample, pretreatment and posttreatment counts from the same tires were compared to determine longevity of effect.

Sampling was enhanced by the use of vacuum aspirators, modified after the design of Livdahl and Willey (1991). A long quick-disconnect vacuum hose was run from the engine of a pickup truck to a 9.5-liter rigid plastic container. From the container, a short length of garden hose was used to suction the contents from the tire. The collected material flowed directly into the 9.5-liter container, which was then emptied, rinsed, and sieved. Macroinvertebrates were transferred by pipette into vials for identification or back into the original water for return to the tire.

To minimize the possibility of contamination from adjacent treatments, samples were collected from tires in the center of each sector. Buffer zones of approximately 2 m along the north and south perimeter of each sector were excluded from the sampling. These zones had received full treatment, but because of their proximity to the adjacent treatment sector it was deemed possible that the perimeters may have been exposed to the adjacent treatment.

The raw data were analyzed by general linear model (GLM) (SAS Institute 1985). Analysis of the 10-tire samples after week 3 was thwarted by seasonal reductions in the untreated controls.

RESULTS

All 837 *Aedes* larvae collected were *Ae. albopictus*. Only 62 *Culex* spp. larvae were collected, all in the 50-tire untreated check plots. Although *Culex* larvae were not detected in the treated plots, the samples are considered too small for statistical comparisons between treated and untreated plots. Changes in pupal density were extremely variable, as was expected, because of the insensitivity of pupae to temephos and the random and uncontrolled age distribution of late-instar larvae and pupae. Thus, pupae were excluded from the analyses of the effects of the treatments. Pupal survivors were not subject to microscopic examination, but those that successfully emerged in the holding vials were all *Ae. albopictus*.

Immediate impact, 50-tire samples: Observations on larval density in 50 tires revealed mean population reduction ranging from 90 to 100% in the treated plots when compared to the untreated check plots (Table 1). At 1.12 kg AI/ha, 99–100% reduction was achieved. At

Table 1. Mean percentage reduction of *Aedes albopictus* larvae in 2 replicates of 50 tires 2 days following granular applications of temephos compared to observations in untreated controls in the same tire pile.

	Kilograms of temephos per hectare				
	0.11	0.56	1.12	11.21	22.42[1]
No. larvae collected	90 a[2]	98 b	99 b	100 b	100 b
Mean per tire	90 a	98 b	99 b	100 b	100 b
Mean per infested tire	81 a	58 ab	88 b	100 b	100 b
No. infested tires	48 a	95 b	97 b	100 b	100 b

[1] Unreplicated.
[2] Means in the same row followed by the same letter are not significantly different at the 95% level.

higher rates, 100% reduction was observed in all plots.

Immediate impact, 6-tire samples: Larval density in the untreated check plots declined 25–69% (mean 47%) between pretreatment and posttreatment collections from the 6 sentinel tires per plot that were observed once prior to application and once posttreatment (Table 2). At 0.11 kg AI/ha, 91% reduction in larval density was observed in both replications, giving adjusted (Abbott's formula) reductions of 71% and 88% (mean 80%). Complete larval control was observed at 0.56, 11.21, and 22.42 kg AI/ha. At 1.12 kg AI/ha, 97% larval reduction was observed in one replicate (adjusted level, 90%), with the other replicate providing complete control for an adjusted mean of 95%. Again, pupal densities were not correlated with application rates.

Long-term impact, 10-tire samples: The 10 sentinel tires in each replicate were monitored weekly for 8–12 wk, and then monthly through the winter (Table 3). Larval density in the winter was too low to determine treatment effect, but populations in the untreated checks rebounded in the spring, allowing the continuation of observations. Excellent control was observed at 0.56 kg AI/ha through 8 wk. During this period, infestation rates in the corresponding untreated checks declined gradually from a mean of 18.6 larvae per infested tire to 2.8, whereas the treated group density remained at zero with the exception of one larva collected in week 3. Results were inconsistent at 1.12 kg AI/ha; with complete control for 7 wk in one replicate and no control after day 2 in the other. The 11.21 kg AI/ha application rate maintained complete control through the winter (9–10 wk) and into spring (5 months), as did the 22.42 kg AI/ha unreplicated treatment.

DISCUSSION

Application of the corncob grit granules was unexpectedly effective in terms of granule distribution. The blower efficiently propelled the granules to the top of the tire pile in all but the most windy conditions (which may have been associated with the reduced effectiveness of one replication at the 1.12 kg AI/ha rate). The operator was able to remain on the ground when making the applications. This may be an important feature in terms of worker safety and speed of application. In addition, the granules ricocheted repeatedly from tire to tire resulting in excellent distribution and penetration to a depth of at least 1.3 m into the tire piles. Granules were found in the collection samples from all 750 tires in the short-term test, which was designed to observe this parameter.

The 6-tire and 10-tire samples were independent and different measures of the immediate

Table 2. Mean percentage reduction of *Aedes albopictus* larvae in 2 replicates of 6 tires 2 days following granular applications of temephos compared to pretreatment observations in the same tire.

	Kilograms of temephos per hectare					
	0	0.11	0.56	1.12	11.21	22.42[1]
No. larvae collected	47 a[2]	91 b	100 b	99 b	100 b	100 b
Mean per tire	47 a	91 b	100 b	99 b	100 b	100 b
Mean per infested tire	37 a	88 b	100 b	91 b	100 b	100 b
No. infested tires	20 a	25 a	100 b	92 b	100 b	100 b

[1] Unreplicated.
[2] Means in the same row followed by the same letter are not significantly different at the 95% level.

Table 3. Mean percentage reduction of *Aedes albopictus* larvae in 2 replicates of 10 tires following temephos granular applications compared to observations in untreated controls in the same tire pile.

Time posttreatment	Kilograms of temephos per hectare				
	0.11	0.56	1.12	11.21	22.42[1]
2 days	67[2]	97[2]	96/88[2,3]	100[2]	100[2]
1 wk	93	100	100/0[2]	100[2]	100[2]
2 wk	96	100	100/59[2]	100[2]	100[2]
3 wk	86	96	100/15	100	100[4]
4 wk	42	100	100/0	100	100
5 wk	86	100	100/31	100	100
6 wk	100[1]	100[1]	100/0	100[1]	100
7 wk	50[1]	nc[4]	100/nc	100	100
8 wk	0[1]	100[1]	nc/33	nc	nc
9 wk	89[1]	92[1]	23/nc	100	100[2]
10 wk	nc	nc/0[1]	nc/0	nc	100
11 wk	nc	nc	100/nc	100[1]	100
5 months	nc	nc	100/nc	100	100

[1] Unreplicated.
[2] Result significantly different from controls of the same time posttreatment.
[3] Replicate 1/replicate 2.
[4] No collection.

impact of the treatments, yet the results between the 2 measures were substantively the same for the 0.11, 0.56, 1.12, and 11.21 kg AI/ha treatment rates (Tables 1 and 2). This suggests that the efficiency of the larval collection method was very high. Suction from the vacuum collection system was adequate to evacuate several liters from a tire in less than a minute while the tires remained in place during the collection process. Thus, not all water or silt was evacuated from each tire and some invertebrates undoubtedly escaped collection. After collecting a sample from short-term tires (50-tire samples), some tires were moved to provide better access to underlying tires; additional samples were not taken from the moved tires. The long-term tires (10-tire samples) were not moved. Some invertebrates were undoubtedly lost in the solid residue taken from the tires along with the sample. Both of the above factors are considered to have had relatively uniform effect on all the collections, and thus to have exerted little or no bias toward any particular treatment group. Finally, 1st-stage larvae were seldom captured by the sieves and, in the rare event that they were, their presence was recorded but not used in the efficacy calculations. This policy was adopted because it was impossible to control posttreatment eclosion from the egg and newly hatched larvae had unknown exposure duration to the temephos. By eliminating 1st-instar larvae from both the pretreatment and posttreatment analyses, bias was avoided.

Morris and Robinson (1994) reported the occurrence of the following invertebrates in these tires in 1992: *Ae. aegypti, Ae. albopictus, Aedes triseriatus* (Say), *Culex nigripalpus* (Theobald), *Toxorhynchites rutilis rutilis* (Coquillett), *Corethrella* spp., and chaoborids. In 1993 and 1994, neither *Ae. aegypti* nor *Tx. r. rutilis* were detected in the samples. But in both years the density of *Corethrella* spp. and chaoborids was substantially reduced in the posttreatment samples of the higher application rates. Numerical density of these invertebrates was not recorded, but the reduction in incidence was apparent.

The results of these studies indicate that prolonged control of *Ae. albopictus* can be achieved at half (11.21 kg AI/ha) the maximum allowable application rate. In fact, it appears that excellent control can be expected at rates as low as 0.56 kg AI/ha. The ease of application and the excellent distribution and penetration of the corncob grit granule into the tire pile suggest that both cost and manpower can be substantially reduced by use of the corncob formulation.

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REFERENCES CITED

Abbott, W. S. 1925. A method for computing the effectiveness of an insecticide. J. Econ. Entomol. 18: 265–267.

Beehler, J. W., T. C. Quick and G. R. DeFoliart. 1991. Residual toxicity of four insecticides to *Aedes triseriatus* in scrap tires. J. Am. Mosq. Control Assoc. 7:119–120.

Hobbs, J. H., E. A. Hughes and B. H. Eichold II. 1991. Replacement of *Aedes aegypti* by *Aedes albopictus* in Mobile, Alabama. J. Am. Mosq. Control Assoc. 7:488–489.

Livdahl, T. and M. Willey. 1991. An efficient, inexpensive and fun-to-use contraption for sampling mosquito larvae. J. Am. Mosq. Control Assoc. 7: 496–498.

Mitchell, C. J., M. L. Niebylski, G. C. Smith, N. Karabatsos, D. Martin, J.-P. Mutebi, G. B. Craig, Jr. and M. J. Mahler. 1992. Isolation of eastern equine encephalitis virus from *Aedes albopictus* in Florida. Science 257:526–527.

Morris, C. D. and J. W. Robinson. 1994. Distribution of mosquito larvae in a waste tire pile in Florida—an initial study. J. Am. Mosq. Control Assoc. 10: 174–180.

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. 4:449–453.

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.

O'Meara, G. F., L. E. Evans, Jr., A. D. Gettman and J. P. Cuda. 1995. Spread of *Aedes albopictus* and decline of *Ae. aegypti* (Diptera: Culicidae) in Florida. J. Med. Entomol. 32:554–562.

SAS Institute, Inc. 1985. SAS user's guide: statistics, version 5 ed. SAS Institute, Inc., Cary, NC.

Scott, T. W., L. H. Lorenz and S. C. Weaver. 1990. Susceptibility of *Aedes albopictus* to infection with eastern equine encephalomyelitis virus. J. Am. Mosq. Control Assoc. 6:274–278.