

EFFICACY OF THREE SYNTHETIC PYRETHROIDS AGAINST THREE MOSQUITO SPECIES IN ARKANSAS AND LOUISIANA

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ABSTRACT. Adult mortality of *Anopheles quadrimaculatus*, *Culex quinquefasciatus*, and *Aedes sollicitans* was observed following ultra-low-volume (ULV) exposure to Responde®, Permanone® 31-66 RTU, and Scourge®. Permanone 31-66 RTU (1:2.13, permethrin:PBO) and Scourge (1:3, resmethrin:PBO) were applied at 0.00175 lb AI/acre, while Responde (1:3, prallethrin:PBO) was applied at 0.001 lb AI/acre, and all were evaluated at 100, 200, and 300 ft. downwind of application. Significant mortality differences ($P \leq 0.05$) were observed among all compounds at 15 min and at 1, 12, and 24 h posttreatment against *An. quadrimaculatus* and *Cx. quinquefasciatus*. Responde exhibited significantly greater ($P \leq 0.05$) control (knockdown) against *An. quadrimaculatus* at both 15 min and 1 h posttreatment than did Permanone 31-66 RTU or Scourge; however, some recovery occurred by 12 h posttreatment. At 15 min posttreatment, Responde and Scourge were significantly ($P \leq 0.05$) more effective against *Cx. quinquefasciatus* than Permanone 31-66 RTU except at 300 ft. downwind, where Scourge was significantly ($P \leq 0.05$) more effective than either compound. No significant mortality differences ($P \leq 0.05$) were observed among the 3 compounds at 15 min, 1 h, 12 h, and 24 h posttreatment when tested against *Ae. sollicitans*. No significant mortality differences ($P \leq 0.05$) were observed between the 1:3 and 1:5 (prallethrin:piperonyl butoxide) formulations of Responde at any time posttreatment when tested against *Ae. sollicitans*.

INTRODUCTION

Traditionally, ultra-low-volume (ULV) insecticidal sprays have been applied in concentrate or diluted in a light oil (Weathersbee et al. 1986, Groves et al. 1994). The use of synthetic pyrethroids has also allowed for the dramatic reduction in dosage rates or active ingredient per acre (Meisch et al. 1994). Historically, diluents, including heavy oils or diesel, have been used with synthetic pyrethroids because of their simplicity of use and reduced cost (Sandoski et al. 1983, Efrid et al. 1991). However, with increasing environmental contamination concerns, other forms of synthetic pyrethroids must be considered and evaluated for the continued success of mosquito abatement. In these tests, the effects of a newly formulated synthetic pyrethroid, prallethrin, were examined against 3 mosquito species in Arkansas and Louisiana.

Caged *Anopheles quadrimaculatus* Say, *Culex quinquefasciatus* Say, and *Aedes sollicitans* (Walker) were subjected to field applications of ULV concentrations of Permanone® 31-66 RTU, Scourge®, and Responde®. Wild populations of adult *An. quadrimaculatus* were used for tests conducted at the Rice Research and Extension Center (RREC) near Stuttgart, AR. Wild populations of adult *Cx. quinquefasciatus* and *Ae. sollicitans* were used for tests conducted at the Louisiana State University Experimental Farm, St. Gabriel, LA. Caged-mosquito tests were conducted to evaluate whether Responde, at a lower dosage (0.001 lb AI/acre), had as

great an impact on adult mosquito mortality as Permanone 31-66 RTU and Scourge at higher dosages (0.00175 lb AI/acre). Differences in mortality among distances and between species were evaluated.

MATERIALS AND METHODS

Using a backpack aspirator (U.S. Department of Agriculture, Medical and Veterinary Entomology Research Laboratory, Gainesville, FL), adult *An. quadrimaculatus* were collected from a livestock barn approximately 1 mi. north of the city of Almyra, AR, in Arkansas County. Adult *Cx. quinquefasciatus* were collected from a septic ditch in East Baton Rouge Parish, LA, while a biting or landing collection of adult *Ae. sollicitans* was collected from persons in Vermilion Parish near Abbeville, LA. Mosquitoes were then transported to the laboratory and were briefly anesthetized using CO₂ and transferred to cylindrical screened cages (5.2 × 8.6 cm) (Sandoski et al. 1983). Approximately 20 adult mosquitoes were placed in each cage. Mean overall sex ratio of female: male was calculated to be 10.4:1 for all tests including *An. quadrimaculatus* and *Cx. quinquefasciatus*. All test cages containing adult mosquitoes were then held at 72°F and 40.0% relative humidity until just prior to conducting the test.

Test plots consisting of 3 rows of 3 stakes/row were set up in fallow fields at the Rice Research and Extension Center, Stuttgart, AR, and in pasture land at Louisiana State University Experiment Station, St. Gabriel, LA. Rows were separated by 100 ft., and the 3 stakes within each row were 100, 200, and 300 ft. downwind from and perpendicular to the spray path. Cages of adult mosquitoes were suspended from each stake approximately 5 ft. above ground. During some of the tests in St. Gabriel, LA,

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two cages were hung from each stake during some replications.

Ground ULV applications of Permanone 31-66 RTU (1:2.13, permethrin:piperonyl butoxide) and Scourge (1:3, resmethrin:piperonyl butoxide) were applied at 0.00175 lb AI/acre. Responde (1:3, prallethrin:piperonyl butoxide) was applied at 0.001 lb AI/acre during these tests. Tests were replicated 3 times on August 8 and 9, 1995, in Stuttgart, AR, and again on August 14-16, 1995, in St. Gabriel, LA, between 8:00 and 11:30 pm. An additional unreplicated comparison of Responde was also conducted in Stuttgart, AR, at 0.001 and 0.00125 lb AI/acre against *An. quadrimaculatus*. In an additional test at St. Gabriel, LA, against *Ae. sollicitans*, Responde at a 1:5 formulation (prallethrin:piperonyl butoxide) was compared with that at a 1:3 formulation.

Applications were conducted using a London Aire® 1820 cold aerosol generator driven at 10 mph with a nozzle pressure of 8 psi and a flow rate of 8 oz./min for all replications. The application sequence was randomized and the equipment was flushed between applications with Orchex®, the common carrier for each formulation. Orchex droplets measured with an AIMS unit averaged 16.5 µm. During tests conducted in Stuttgart, AR, on August 8, the temperature ranged from 82.7 to 86.7°F, while wind speed averaged 2.2 mph and wind direction was from the southeast (160° azimuth); on August 9, temperatures ranged from 80.0 to 82.2°F, while wind speed averaged 1.1 mph and wind direction was again from the southeast. At St. Gabriel, LA, on August 14-16, wind speed averaged 1.5 mph, while wind direction was variable. Temperature at ground level ranged from 82.0 to 84.4°F during testing. Suitable conversion conditions were present each evening at both locations.

Slide spinners (John W. Hock Co., P. O. Box 12852, Gainesville, FL 32604) were used to monitor the spray cloud. In most replications, spinners were placed on each stake in the center row to collect droplets. Teflon®-coated slides were placed in the spinners, which were started immediately before spraying and were allowed to spin for approximately 10 min.

Treatment cages containing adult mosquitoes were placed one, or sometimes 2, per stake just prior to exposure and allowed to remain for 10 min posttreatment. Control cages were placed on stakes within the test plots and allowed to stand for approximately 10 min and were subsequently removed prior to ULV application.

After each replication, exposed cages were immediately transported to the laboratory, where the mosquitoes were anesthetized briefly with CO₂ and transferred to clean 237-ml paper cups (Napco Company, Springdale, AR 72764) with screen lids. A solution of 10% sugar water was offered on cotton pads placed on the surface of each screen lid.

Table 1. Evaluation of Permanone, Scourge, and Responde tested at 3 distances against *Anopheles quadrimaculatus* on August 8 and 9, 1995, at the Rice Research and Extension Center in Stuttgart, AR.

| Time interval | Chemical | Mean percentage mortality ¹ (distance downwind) | | |
|---------------|-----------|---|----------|----------|
| | | 100 ft. | 200 ft. | 300 ft. |
| 15 min | Permanone | 6.9 aC | 5.5 aB | 13.0 aB |
| | Scourge | 29.0 aB | 23.8 aB | 18.3 aB |
| | Responde | 52.7 aA | 68.0 aA | 62.7 aA |
| | Control | 0.0 | 0.0 | 0.0 |
| 1 h | Permanone | 33.7 aB | 27.0 aC | 38.6 aB |
| | Scourge | 52.5 aB | 56.4 aB | 54.0 aAB |
| | Responde | 66.0 aA | 84.2 bA | 70.8 aA |
| | Control | 0.57 | 0.57 | 0.57 |
| 12 h | Permanone | 42.5 aA | 36.6 aB | 41.9 aA |
| | Scourge | 60.6 aA | 61.5 aA | 54.2 aA |
| | Responde | 52.6 aA | 68.9 bA | 53.0 aA |
| | Control | 2.3 | 2.3 | 2.3 |
| 24 h | Permanone | 46.4 aA | 43.1 aB | 46.0 aA |
| | Scourge | 59.6 aA | 60.9 aAB | 57.8 aA |
| | Responde | 55.8 aA | 68.0 aA | 57.3 aA |
| | Control | 3.2 | 3.2 | 3.2 |

¹ Means of 3 replications reported from retransformed data analyzed by GLM. Means not followed by the same letter within rows (lowercase) are significantly different ($\alpha = 0.05$) by Duncan's multiple-range test. Within-column comparisons (uppercase) for the same time intervals were significantly different ($\alpha = 0.05$). Means have been corrected for control mortality according to Abbott (1925).

Percentage mortality was observed at 15 min, 1 h, 12 h, and 24 h posttreatment.

Percentage mortality data were subjected to an arcsine (%/100) transformation and a subsequent analysis of variance (GLM). Means were corrected by Abbott's formula (Abbott 1925), and mean separation was subsequently conducted using Least Squared Means (SAS Institute 1985).

RESULTS AND DISCUSSION

Significant mortality differences ($P \leq 0.05$) were observed among the 3 compounds against *An. quadrimaculatus* (Table 1). Responde was superior at the 15-min and 1-h intervals posttreatment. At 15 min posttreatment, Responde was significantly ($P \leq 0.05$) more effective than either Permanone 31-66 RTU or Scourge. Scourge appeared to be more effective than Permanone 31-66 RTU up to 1 h posttreatment, but the differences were not consistently significant ($P \leq 0.05$). At 1 h posttreatment, the results were essentially the same as those at 15 min posttreatment. Responde was still significantly more effective; however, some recovery was observed at 1 h. Trends were similar at 12 and 24 h posttreatment, although statistical significance was not observed in most instances. The only statistically significant difference in distance down-

Table 2. Evaluation of Permanone, Scourge, and Responde tested at 3 distances against *Culex quinquefasciatus* on August 14 and 15, 1995, at the Louisiana State Experiment Station, St. Gabriel, LA.

| Time interval | Chemical | Mean percentage mortality ¹ (distance downwind) | | |
|---------------|-----------|---|---------|----------|
| | | 100 ft. | 200 ft. | 300 ft. |
| 15 min | Permanone | 31.7 aB | 19.8 aB | 27.4 aB |
| | Scourge | 39.7 aA | 46.8 aA | 57.4 aA |
| | Responde | 60.9 aA | 58.7 aA | 29.3 bB |
| | Control | 1.2 | 1.2 | 1.2 |
| 1 h | Permanone | 47.8 aA | 35.1 aA | 38.3 aB |
| | Scourge | 61.2 aA | 71.8 aA | 70.6 aA |
| | Responde | 52.4 aA | 61.2 aA | 41.5 aB |
| | Control | 7.9 | 7.9 | 7.9 |
| 12 h | Permanone | 56.1 aA | 40.5 aB | 50.9 aB |
| | Scourge | 62.4 aA | 73.8 aA | 81.1 aA |
| | Responde | 69.6 aA | 70.4 aA | 53.5 aAB |
| | Control | 18.5 | 18.5 | 18.5 |
| 24 h | Permanone | 57.6 aA | 40.7 aB | 52.8 aB |
| | Scourge | 60.6 aA | 79.4 aA | 85.8 aA |
| | Responde | 73.3 aA | 70.4 aA | 58.3 aB |
| | Control | 19.9 | 19.9 | 19.9 |

¹ Means of 3 replications reported from retransformed data analyzed by GLM. Means not followed by the same letter within rows (lowercase) are significantly different ($\alpha = 0.05$) by Duncan's multiple-range test. Within-column comparisons (uppercase) for the same time intervals were significantly different ($\alpha = 0.05$). Means have been corrected for control mortality according to Abbott (1925).

wind occurred between 12 and 24 h posttreatment at 200 ft. downwind.

Significant mortality differences ($P \leq 0.05$) were observed among the three compounds tested against *Cx. quinquefasciatus* (Table 2). At 15 min posttreatment, Responde and Scourge were significantly ($P \leq 0.05$) more effective than Permanone 31-66 RTU except at 300 ft. downwind, where Scourge was significantly ($P \leq 0.05$) more effective than either compound. Mortality decreases at 300 ft. were consistent for Responde throughout this test against *Cx. quinquefasciatus*, perhaps indicating a poor carry of the compound. At 1 h posttreatment, Scourge was significantly ($P \leq 0.05$) superior at 300 ft. downwind. Observations were similar at both 12 and 24 h posttreatment, at which Responde and Scourge appeared more effective than Permanone 31-66 RTU. There was no indication of recovery from early knockdown with this species.

There were no significant differences ($P \leq 0.05$) in effectiveness among any of the compounds tested against *Ae. sollicitans* (Table 3). This species had high check mortality at later time periods. This often occurs with floodwater species, which are notoriously cage-intolerant (W. R. Horsfall, personal communication). Control mortalities were consistent, and no tolerance or susceptibility differences were noted.

Table 3. Evaluation of Permanone, Scourge, and Responde tested at 3 distances against *Aedes sollicitans* on August 15 and 16, 1995, at the Louisiana State Experiment Station, St. Gabriel, LA.

| Time interval | Chemical | Mean percentage mortality ¹ (distance downwind) | | |
|---------------|-----------|---|---------|----------|
| | | 100 ft. | 200 ft. | 300 ft. |
| 15 min | Permanone | 25.8 aA | 18.6 aA | 28.0 aA |
| | Scourge | 22.1 aA | 17.9 aA | 15.3 aA |
| | Responde | 23.0 aA | 23.7 aA | 12.5 aA |
| | Control | 3.8 | 3.8 | 3.8 |
| 1 h | Permanone | 48.7 aA | 49.0 aA | 47.1 aA |
| | Scourge | 50.7 aA | 27.7 bA | 38.3 abA |
| | Responde | 52.5 aA | 42.3 aA | 37.3 aA |
| | Control | 9.5 | 9.5 | 9.5 |
| 12 h | Permanone | 71.2 aA | 65.5 aA | 55.9 aA |
| | Scourge | 73.3 aA | 58.2 aA | 50.6 aA |
| | Responde | 65.9 aA | 49.4 aA | 55.4 aA |
| | Control | 16.3 | 16.3 | 16.3 |
| 24 h | Permanone | 76.3 aA | 67.8 aA | 57.9 aA |
| | Scourge | 72.7 aA | 65.5 aA | 57.1 bA |
| | Responde | 72.1 aA | 50.9 bA | 66.2 abA |
| | Control | 22.3 | 22.3 | 22.3 |

¹ Means of 3 replications reported from retransformed data analyzed by GLM. Means not followed by the same letter within rows (lowercase) are significantly different ($\alpha = 0.05$) by Duncan's multiple-range test. Within-column comparisons (uppercase) for the same time intervals were significantly different ($\alpha = 0.05$). Means have been corrected for control mortality according to Abbott (1925).

Results obtained from the pretrial nonreplicated test against *An. quadrimaculatus* of two dosages of Responde illustrated few consistent significant differences ($P \leq 0.05$) between 0.001 and 0.00125 lb AI/acre, with the exception of 200 ft. (Table 4). Because this test had some equipment malfunction and was not replicated, results obtained preclude any conclusive findings. The test was useful, however, in that procedures and techniques were established for subsequent tests.

No significant mortality differences ($P \leq 0.05$) were observed in the test comparing 2 formulations of Responde at 1:3 and 1:5 (prallethrin:piperonyl butoxide) against *Ae. sollicitans* from 15 min through 24 h posttreatment (Table 5). Significant differences ($P \leq 0.05$) occurred among distances tested for all times posttreatment. The formulation of Responde mixed 1:3 was as effective against the test mosquitoes as was the 1:5 formulation.

Droplet observations revealed impingement on Teflon®-coated slides at most locations sampled, indicating that the aerosol cloud had passed through the entire plot for all replications of all compounds tested. In some instances, however, the number of droplets collected was not sufficient to determine mean size or to accurately reflect droplet density. Specifically, the tests conducted in Louisiana on calm nights afforded intermittent testing opportunities when wind velocity increased sufficiently to

Table 4. Evaluation of 2 rates of Responde tested at 3 distances against *Anopheles quadrimaculatus* at the Rice Research and Extension Center in Stuttgart, AR.

| Time interval | Chemical rate (lb AI/acre) | Mean percentage mortality ¹ (distance downwind) | | |
|---------------|----------------------------|--|----------|---------|
| | | 100 ft. | 200 ft. | 300 ft. |
| 15 min | Responde (0.001) | 10.9 aA | 36.0 bA | 39.0 bA |
| | Responde (0.00125) | 11.3 aA | 8.3 aB | 36.5 bA |
| | Control | 0.53 | 0.53 | 0.53 |
| 1 h | Responde (0.001) | 18.8 aA | 34.5 abA | 49.2 bA |
| | Responde (0.00125) | 14.7 abB | 8.0 aB | 31.1 bB |
| | Control | 1.3 | 1.3 | 1.3 |
| 12 h | Responde (0.001) | 19.5 aA | 50.2 bA | 44.9 bA |
| | Responde (0.00125) | 16.8 aA | 15.2 aB | 35.8 bA |
| | Control | 2.9 | 2.9 | 2.9 |
| 24 h | Responde (0.001) | 20.3 aA | 51.8 aA | 46.6 aA |
| | Responde (0.00125) | 16.8 aA | 15.2 aB | 41.5 aA |
| | Control | 3.3 | 3.3 | 3.3 |

¹ Retransformed data analyzed by GLM. Data not followed by the same letter within rows (lowercase) are significantly different ($\alpha = 0.05$) by Duncan's multiple-range test. Within-column comparisons (uppercase) for the same time intervals were significantly different ($\alpha = 0.05$). Data have been corrected for control mortality according to Abbott (1925).

move the aerosol cloud. However, the field notes and on-site automated weather information reveal that conditions were suitable for spray. Droplet sizes (MMDs) for the compounds tested in Arkansas averaged 11.6, 14.5, and 10.4 μm for Responde, Permanone, and Scourge, respectively, for all replications. Droplet sizes for the compounds tested in Louisiana averaged 13.9, 14.1, and 15.5 μm for Responde, Permanone, and Scourge, respectively, for all replications.

Throughout this series of experiments, Responde compared very favorably with, and in some instances was superior to, both Permanone and Scourge. This occurred despite Responde being applied at a lower dosage of 0.001 lb AI/acre as opposed to 0.00175 lb AI/acre for the other 2 compounds. Thus, except in the few instances in which Scourge provided greater kill than Responde, it is reasonable to conclude that it took 40% less Responde to achieve results the same as or better than those with Permanone RTU or Scourge. Against *An. quadrimaculatus*, Responde was clearly more effective than the other compounds at 15 min and 1 h posttreatment, although recovery was noted at this dosage level with this species. Since compounds for the entire experiment were applied below label recommendations, these low dosages

Table 5. Evaluation of 2 formulations of Responde: piperonyl butoxide tested at 3 distances against *Aedes sollicitans* on August 15, 1995, at the Louisiana State University Experiment Station at St. Gabriel, LA.

| Time interval | Chemical formulation (Responde : PBO) | Mean percentage mortality ¹ (distance downwind) | | |
|---------------|---------------------------------------|--|----------|---------|
| | | 100 ft. | 200 ft. | 300 ft. |
| 15 min | Responde (1:3) | 23.0 aA | 23.8 aA | 12.5 bA |
| | Responde (1:5) | 33.6 aA | 24.2 aA | 30.0 aA |
| | Control | 3.7 | 3.7 | 3.7 |
| 1 h | Responde (1:3) | 52.5 aA | 42.3 abA | 37.3 bA |
| | Responde (1:5) | 65.7 aA | 55.1 aA | 43.9 bA |
| | Control | 9.5 | 9.5 | 9.5 |
| 12 h | Responde (1:3) | 65.9 aA | 58.2 aA | 55.4 aA |
| | Responde (1:5) | 67.2 aA | 61.4 aA | 48.6 bA |
| | Control | 17.4 | 17.4 | 17.4 |
| 24 h | Responde (1:3) | 72.1 aA | 65.5 aA | 66.2 aA |
| | Responde (1:5) | 69.9 aA | 63.5 abA | 50.1 bA |
| | Control | 22.8 | 22.8 | 22.8 |

¹ Means of 3 replications reported from retransformed data analyzed by GLM. Means not followed by the same letter within rows (lowercase) are significantly different ($\alpha = 0.05$) by Duncan's multiple-range test. Within-column comparisons (uppercase) for the same time intervals were significantly different ($\alpha = 0.05$). Means have been corrected for control mortality according to Abbott (1925).

might well allow recovery from initial knockdown. However, this recovery phenomenon was not observed against any other species tested. Responde was superior (percentage) to Permanone 31-66 RTU and Scourge at 15 min and 1 h posttreatment against *Cx. quinquefasciatus* but appeared equal with the other compounds against *Ae. sollicitans*.

Throughout the entire test series, Responde and Scourge seemed superior to Permanone 31-66 RTU except against *Ae. sollicitans*. This superiority was especially pronounced against *An. quadrimaculatus*. Explanation of these findings may require additional tests. The ratios of 1:3 and 1:5 prallethrin to piperonyl butoxide were compared against *Ae. sollicitans*; however, the results were inconclusive.

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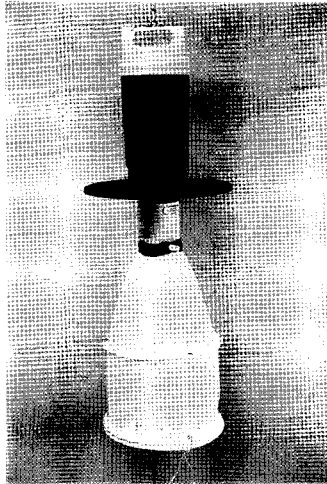
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