LABORATORY WIND TUNNEL TESTS OF NINE INSECTICIDES AGAINST ADULT *CULICOIDES* SPECIES (Diptera: Ceratopogonidae)

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ABSTRACT

Nine insecticides were tested against field collected adult sand flies in a non-thermal wind tunnel. *Culicoides mississippiensis* Hoffman represented more than 90% of the total sand flies tested. The insecticides included 5 organophosphate (OP) compounds (malathion, naled, fenitrothion, fenthion, and chlorpyrifos), 3 pyrethroids (resmethrin, phenothrin and permethrin) and a combination of malathion/resmethrin (90:1). Mortality was recorded at 1, 4, and 24 h posttreatment. Malathion, the standard, was intermediate among the OP compounds in effectiveness at the 24-h, LC_{90}, level. The OP compounds exhibited poor knockdown at the LC_{90} dosage levels and the addition of resmethrin to malathion only slightly increased the knockdown of malathion. The pyrethroids exhibited nearly 100% knockdown 1 h posttreatment at both the LC_{50} and LC_{90} levels, but some individual sand fly recovery occurred 24 h later.

RESUMEN

Se probaron en un túnel de viento no-termal, 9 insecticidas contra moscas de arena colectadas en el campo. *Culicoides mississippiensis* Hoffman representó más de un 90% de todas las moscas de arena probadas. Los insecticidas incluyeron 5 compuestos de organofosfatos (malathion, naled, fenitrothion, fenthion, y chlorpyrifos), 3 pyrethroids (resmethrin, phenothrin, y permethrin), y una combinación de malathion/resmethrin (90:1). Se registró la mortalidad a la 1, 4, y 24 horas despueś del tratamiento. Malathion, el patrón, fue intermedio en su infectividad entre los compuestos de organofosfatos a las 24 hrs., a un nivel de CL_{90} (CL=concentración letal). La rapidez con que los compuestos de organofosfatos ejercieron mortalidad fue muy lenta con la dosis de LC_{90}, y añadiendole resmethrin al malathion solo aumentó la mortalidad del malathion. Los pyrethroids demostraron casi un 100% de mortalidad 1 hr. despueś del tratamiento a ambos niveles de CL_{50} y CL_{90}, pero algunas moscas de arena se recuperaron 24 hrs. después.

Biting midges or sand flies (*Culicoides* spp.) are annoying insect pests in some coastal areas of Florida. They easily pass through standard window screen and may be annoying indoors as well as outdoors (Goodin 1980). Linley and Davies (1971) suggested that sand fly annoyance was detrimental to tourism in some areas of the state. Medically, *Culicoides* have been implicated as vectors of several pathogens of wild and domestic animals and man (Blanton and Wirth 1979).

In the past, sand fly control has been directed against the larval stages either as source reduction or as chemical application (Harrington and Bidlingmayer 1958, Rogers 1962, Clements and Rogers 1968). However, increasing environmental concerns and controls are making larval control impractical and unacceptable. Adult sand fly control has been limited to repellents, exclusion screens and/or insect repellent jackets (Schreck et al. 1979a, Schreck et al. 1979b). Giglioli et al. (1980), Kline et al. (1981), and the West Florida Arthropod Research Laboratory (WFARL) have initiated research to determine if adult sand flies may be controlled by routine adult mosquito control methods. This paper reports results obtained at WFARL on 9 adulticides; 5 organophosphate (OP) compounds (malathion, naled, fenitrothion, fenthion, and chlorpyrifos), 3 pyrethroids (resmethrin, permethrin, and phenothrin) and a malathion/resmethrin (90:1) mixture tested in a laboratory wind tunnel against field collected adult sand flies.

Materials and Methods

Adult sand flies were collected with a modified CDC trap using dry ice as an attractant. The traps were placed at the field site in the late afternoon and the following morning they were returned to the laboratory. The sand flies were collected in 90 mm diam X 165 mm long cylindrical cardboard containers and held in a 44 X 35 X 30 cm styrofoam cooler (Floore 1982). At the laboratory, actively flying adults were transferred to a 90 mm diam X 83 mm long cardboard container covered with a cotton pad containing a 10% sugar water solution. The sand flies were tested within 6 h of returning to the laboratory. The cardboard containers were replaced as needed, but usually lasted several weeks.

The sand flies were anesthetized with CO_2 in the small container and ca. 70 flies were aspirated into a number of other smaller cardboard containers. The bottom of all the containers were replaced with a 150 mm diam piece of 42/40 mesh polyethylene screen fabric (TEKO, Inc., NY) which was secured to the bottom of the container by the ring portion of a cardboard lid and masking tape. A cardboard lid covered the top of the container. The caged sand flies were placed in the test room for 30 min prior to testing to acclimate the flies to the room's environmental conditions (24 ± 5°C and 75 ± 5% R.H.).

The wind tunnel (Rathburn 1969 and Rathburn and Boike 1972) was modified (Ruff, WFARL, unpublished) to accept the cardboard container by inserting a 137 mm diam and 76 mm long wood and metal sleeve into the wind tunnel chamber on the atomizer side of the chamber cover. The sleeve narrowed from 137 mm to 90 mm to accept the container. The wind velocity channeled through the sleeve was ca 2.7 m/sec. (Alnor Instruments, Chicago). The sand flies were observed to be positively phototropic and were attracted to the screened end of the containers toward the light of four 6 V DC lantern bulbs and away from the removable lid.

The container of sand flies with the lid removed was inserted in the wind tunnel with the container's open end toward the atomizer. The sand flies were exposed to 0.5 ml of an insecticide solution sprayed into the wind tunnel at 1.1 kg/cm^2 through the wind tunnel via a DeVilbiss No. 155 atomizer (The DeVilbiss Co., Somerset, PA) for 5 seconds. Five sec later, the cage was removed from the chamber, the lid replaced and the sand flies anesthetized for 2-8 sec with CO_2. Then they were transferred to clean 0.24 liter Mason jars with a 42/40 screen inserted in the ring top. The process from inserting the container in the chamber to tightening the top on the jar required 18-22 seconds. A cotton pad moistened with a 10% sugar solution in water was placed on the screen and the jars were placed in a room maintained at ca. 24 ± 5°C and 65 ± 5% relative humidity. A test of each insecticide consisted of a series of 5 concentrations plus a check of acetone and was replicated 4 to 6 times. The check container and jar were handled in the same manner as each treated cage. Acetone was sprayed through the empty chamber to clean the chamber of any material remaining from the previous treatment. The cardboard containers used for the insecticide tests were discarded after the tests. The screens and mason jars were washed in acetone and baked at ca. 100°C for ca. 12 h in a Precision Scientific oven (Am. Sci. Products) for reuse.

The term "knockdown" (Beard 1960) was used to describe the condition that existed at 1 and 4 h posttreatment. The use of this term made it possible to distinguish between reversible paralysis and death. Some recovery was observed, especially in tests with the pyrethroids. Mortality data were corrected for control mortality by Abbott's formula (Abbott 1925) and the LC_{50} and LC_{90} and corresponding 95% confidence limits were calculated by probit analysis. Malathion was used as the standard because of its extensive use in Florida mosquito control programs.

Approximately 100 adults were retained for later identification from each weeks collections. Representative samples sent to Dr. W. W. Wirth for identification were primarily *C. mississippiensis* with some *C. furens* (Poey) and *C. mellus* (Coquilett) (Wirth, U. S. Natl. Museum, Washington, DC 1982, personal communication). Identifications at this laboratory supported this assessment.

Results and Discussion

The results of the wind tunnel tests against a natural sand fly population summarized in Table 1 show the LC_{50}, LC_{90}, and the corresponding 95% confidence limits for 1, 4, and 24 h posttreatment mortality. The compounds are ranked from the least effective to the most, based on the 24-h, LC_{90} mortality.

TABLE 1. EFFICACY OF SELECTED INSECTICIDES AGAINST A NATURAL POPULATION OF *Culicoides* SPP. EXPOSED IN A LABORATORY WING TUNNEL 1982.

Insecticide	Post-treatment h	Lethal concentrations (mg AI/ml)			
		LC_{50}	95% C.L.[1]	LC_{90}	95% C.L.[1]
naled	1	0.1740	0.1690-0.1790	0.2930	0.2750-0.3140
(Dibrom)	4	0.0910	0.0870-0.0953	0.1932	0.1809-0.2073
	24	0.0586	0.0530-0.0649	0.1530	0.1420-0.1640
fenitrothion	1	0.1509	0.0797-0.2854	3.1176	1.6776-6.0214
(Sumithion)	4	0.0409	0.0386-0.0433	0.0891	0.0830-0.0959
	24	0.0325	0.0304-0.0348	0.0881	0.0817-0.0953
malathion (std)	1	0.0734	0.0658-0.0819	0.2030	0.1580-0.2610
(Cythion)	4	0.0319	0.0305-0.0335	0.0861	0.0773-0.0962
	24	0.0232	0.0219-0.0247	0.0667	0.0603-0.0736
malathion/resmethrin	1	0.0232	0.0211-0.0254	0.1445	0.1164-0.1794
(90:1)	4	0.0104	0.0092-0.0117	0.0886	0.0723-0.1085
	24	0.0067	0.0061-0.0074	0.0335	0.0285-0.0393
chlorpyrifos	1	0.0853	0.0790-0.0922	0.2189	0.1982-0.2418
(Dursban)	4	0.0153	0.0143-0.0164	0.0330	0.0287-0.0386
	24	0.0098	0.0085-0.0012	0.0274	0.0231-0.0324
fenthion	1	*	*	*	*
(Baytex)	4	0.0352	0.0304-0.0407	0.1066	0.0685-0.1660
	24	0.0110	0.0099-0.0124	0.0231	0.0207-0.0258
resmethrin	1	0.0002	0.0001-0.0006	0.0007	0.0004-0.0010
(SBP 1382-40F)	4	0.0008	0.0007-0.0009	0.0021	0.0019-0.0023
	24	0.0007	0.0004-0.0010	0.0135	0.0090-0.0209
permethrin	1	0.00029	0.00027-0.00031	0.0009	0.0008-0.0010
(PRAMEX)	4	0.00043	0.00041-0.00046	0.0011	0.0009-0.0013
	24	0.00050	0.00048-0.00058	0.0025	0.0021-0.0030
phenothrin	1	**	**	0.0016	0.0011-0.0024
(Sumithrin)	4	0.0020	0.0012-0.0032	0.0019	0.0017-0.0022
	24	0.0024	0.0022-0.0027	0.0012	0.0096-0.0131

[1]95% Confidence Limits.
*Unable to determine LC_{50} and/or LC_{90}values statistically due to low mortality at highest dosages tested.
**Unable to determine LC_{50} and/or LC_{90} values statistically due to high mortality at the lowest dosages tested.

Some comparisons can be made between the susceptibility results obtained with the OP compounds, the pyrethroids and between the individual compounds. Naled was the least effective and phenothrin the most effective of the 9 insecticides observed 24 h after treating at the LC_{90} level. Among the OP compounds, malathion, the standard, was intermediate in effectiveness at the LC_{90} level 24 h posttreatment. Chlorpyrifos and fenthion at both the LC_{50} and LC_{90} levels 24 h after treating were more than twice as effective as malathion. None of the OP compounds exhibited rapid knowkdown 1 h posttreatment at the LC_{50} or LC_{90} levels. The efficacy of fenthion 1 h after treatment could not be determined because of the low mortality at the highest dosage tested. Kline et al. (1981) also reported fenthion the least effective compound at 1h posttreatment. Although recovery was observed with each of the 3 pyrethroids tested, they were more effective than the Op compounds at both the LC_{50} and the $LC_{90)}$ levels 1, 4 and 24 h after treating. Kline et al. (1981) and Rathburn et al. (1982) also reported recovery of pyrethroid treated insects over a 24-h period. Resmethrin was the most effective insectivcide tested 1 h after treating at the LC_{90} level. Resmethrin was ca. 290 X more effective than malathion, but at the end of the test its efficacy was only ca. 5 X malathion's.

A mixture of malathion-resmethrin (90:1) was compared to malathion only to try to increase the 1 h knockdown of malathion. A similar study with adult mosquitoes (Rathburn and Boike 1981) demonstrated a slight increase in toxicity with a malathion-resmethrin (90:1) mixture over malathion. This present study indicated a malathion-resmethrin formulation failed to substantially increase the mortality of malathion only at either 1 or 24 h posttreatment at the LC_{90} level. However, the formulation slightly increased the knockdown capability of malathion at the LC_{50} level 1 and 24 h after treatment. The increased cost of the formulation without a substantial increase in its efficacy over malathion only would make it economically impracticable in actual field control practices.

Comparisons of wind tunnel data from different sources and between different insect species should be done with caution because procedures and techniques vary from one facility to another. Laboratory wind tunnel procedures used at WFARL differ depending on the insect species used (Rathburn et al. 1982, unpublished WFARL procedures); however, reproduceability between tests within a study are consistent when utilizing standard procedures and similar insect populations. Wind tunnel data are useful in determining the relative order of effectiveness of a group of insecticides, and to compare the susceptibility of different insect species to various insecticides. Wind tunnel studies also eliminate those insecticides not toxic enough to justify further study, and provide a method of uniform insecticide exposure of test insects which contribute to statistical reliability.

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SUITALBILITY OF POTENTIAL WILD HOSTS OF *DIAPHANIA* SPECIES IN SOUTHERN FLORIDA

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ABSTRACT

The cucurbit weed, *Melothria pendula* L., was found to be an important wild host of pickleworm, *Diaphania nitidalis* (Stoll) and the melonworm, *Diaphania hyalinata* (L.), in southern Florida. Laboratory feeding tests showed that foliage of another abundant cucurbit weed, *Momordica chorantia* L., was unfavorable for larval survival, yet both insect species were found on this plant in field samples. It is believed that pickleworm larvae can develop on *Momordica* flowers and fruit, while melonworms found on *Momordica* may constitute a host race or sibling species.