vectors of onchocerciasis in Uganda. Proc. 10th Internat. Cong. Ent. 3:535–537.

COLLINS, D. L. *et al.* 1952. The application of larvicide by airplane for control of blackflies (Simuliidae). Mosq. News 12:75–77.

FAIRCHILD, G. B., and BARREDA, E. A. 1945. DDT as a larvicide against *Simulium*. Jour. Econ. Ent. 38:694–699.

GJULLIN, C. M. *et al.* 1949. The effect of some insecticides on blackfly larvae in Alaskan streams. Jour. Econ. Ent. 42:100–105.

———, Cross, H. F. and Applewhite, K. H. 1950. Tests with DDT to control blackfly larvae in Alaskan streams. Jour. Econ. Ent. 43:696–697.

———, Sleeper, D. A. and Husman, C. N. 1949. Control of blackfly larvae in Alaskan streams by aerial applications of DDT. Jour. Econ. Ent. 42:392.

HOCKING, B. 1950. Further tests of insecticides against blackflies (Diptera: Simuliidae) and a control procedure. Sci. Agr. 30:489–508.

——— *et al.* 1949. A preliminary evaluation of some insecticides against immature stages of blackflies (Diptera: Simuliidae). Sci. Agr. 29: 69–80.

JAMNBACK, HUGO. 1962. An eclectic method of testing the effectiveness of chemicals in killing blackfly larvae (Simuliidae: Diptera). Mosq. News 22:384–389.

KINDLER, J. B. and REGAN, F. R. 1949. Larvicide tests on blackflies in New Hampshire. Mosq. News 9:108–112.

LEA, A. O. JR. 1955. Two items of equipment useful in blackfly larval control. Jour. Econ. Ent. 48:202–203.

———, and DALMAT, H. T. 1954. Screening studies of chemicals for larval control of blackflies in Guatemala. Jour. Econ. Ent. 47:135–141.

LEBRUM, A. 1954. Methodes de prophylaxie de filariose a *Onchocera volvulus*. Ann. Soc. Belge de Med. Trop. 34:751–795.

MUIRHEAD-THOMPSON, R. C. 1957. Laboratory studies on the reactions of *Simulium* larvae to insecticides. Amer. Jour. Trop. Med. Hyg. 6: 920–934.

TRAVIS, B. V. *et al.* 1951. Strip spraying by helicopter to control blackfly larvae. Mosq. News 11:95–98.

WILTON, D. P., and TRAVIS, B. V. 1965. An improved method for simulated stream tests of blackfly larvae. Mosq. News. 25:118–123.

AN IMPROVED METHOD FOR SIMULATED STREAM TESTS OF BLACKFLY LARVICIDES

D. P. WILTON AND B. V. TRAVIS

Entomology Department, College of Agriculture, Cornell University, Ithaca, N. Y.

The problem of testing chemicals for use as blackfly larvicides has been approached in several principal ways; by means of stream sector tests and by large-scale trough tests conducted beside the stream (Gjullin *et al.* 1949), or by container tests in which the larvae are brought into the laboratory and exposed to the chemicals in battery jars or similar containers (Muirhead-Thompson, 1957; Jamnback, 1962), or in glass tubes (Lea and Dalmat, 1954; W.H.O., 1954). Each of these procedures has both advantages and disadvantages.

Stream sector work has certain inherent advantages simply because the tests are made entirely within the natural environment of the larvae. The disadvantages of stream tests outweigh their advantages, however, especially when large numbers of chemicals are to be tested. Such tests are very time-consuming since an accurate determination of stream flow must be made at each test location. In addition, serious limitations on the number of tests which can be run may be caused by difficulty in locating comparable stream situation where larvae occur throughout an adequate length of stream. This factor may be critical since a given test site can be used only once unless rocks or other objects with larvae attached can be moved in. One of the least desirable features of stream sector testing is the direct addition to the stream of experimental concentrations of chemicals which may prove toxic to much of the stream biota.

Tests conducted outside the stream itself in troughs, jars or tubes are decidedly easier than stream tests but convenience is not the most important advantage of such methods. More significant than convenience is the fact that they allow repeated use of a suitable source of larvae so that a given population may provide adequate numbers for a great many tests. Moreover, since there is no need to add insecticidal materials to the stream, its ecology can remain essentially unaffected by the test procedure. But blackfly larvae are typically inhabitants of fast-moving water. Previously reported tests in quiet, slow-moving water or in containers were made under abnormal environmental conditions and their results may not be as readily applicable to control operations in the field as are those of stream tests.

A simple procedure which combines, in considerable measure, the advantages of stream testing with those of out-of-stream testing while avoiding the more serious disadvantages of each is described in this paper. All equipment used is portable and is set up in the field near a suitable supply of larvae (Figure 1). Stream water is pumped into a reservoir tank from which it is distributed equally to four small V-troughs which serve as miniature streams. A pre-determined number of larvae is established in the troughs prior to testing. Chemicals being tested are metered into these miniature streams and are thoroughly mixed with the stream water at a point above the troughs. The concentrations to which the larvae are exposed are controlled entirely by the concentrations of the chemicals metered into the troughs. Because the work is done some distance from the edge of the stream, these chemicals can filter down through the soil instead of going directly into the stream. Following a test the larvae, con-

FIG. 1.—Apparatus for simulated stream tests with blackflies.

fined in nylon bags, are returned for later observation to the stream from which they were collected.

The equipment consists principally of a small centrifugal pump powered by a gasoline engine plus a lightweight wooden stand with three shelves which support metering bottles, a water reservoir and chambers for mixing test chemicals with the stream water. The stand is 34½ inches high, 34 inches wide, and 25 inches from front to back. The dimensions are not critical but these have proven convenient. At the lower corners of the stand four ½ x 6-inch fully threaded machine bolts serve as legs. These bolts allow the stand to be leveled in the field because each one is threaded through a large nut welded to a triangular metal plate at one corner of the stand.

On the uppermost shelf are placed four two-gallon plastic chemical metering bottles which hold the insecticide being tested. A rigid plastic air tube passes through a one-hole rubber stopper tightly inserted in the neck of each bottle. It extends to the level of a rubber outlet hose attached at the same point above the bottom on each bottle. Air enters the bottles only through the plastic tubes. Since each air tube discharges at the same level near the bottom of the bottle, a constant and uniform head pressure is maintained regardless of the level of fluid in the bottle. The air stream passing up through the contents of the bottle causes agitation which helps to keep particulate formulations in suspension. To restrict and equate the rate of flow from the four bottles, a piece of brass stock with a 1/16-inch hole bored through it is inserted as a nozzle into the discharge end of each hose. In addition, the hoses are provided with spring-loaded clamps.

The largest of the stand's three shelves is made of ½-inch plywood and is located below the metering bottle shelf. It supports a fourteen-gallon cylindrical polyethylene tank which is the water reservoir. Stream water is supplied to the tank through a ¾-inch garden hose by the pump which is equipped with a gate valve on the discharge side. A ¾-inch vertical overflow drain is installed inside the tank with its inlet two inches below the rim. During operations the gate valve is adjusted to supply a slight excess of water and the overflow drain acts to maintain a constant head. The drain passes at a right angle through the wall of the tank and the overflow water is led away through a second length of garden hose. The reservoir discharges at the bottom through a plastic spigot directly into a four-outlet manifold made from ½-inch plastic pipe and plastic "T" and elbow fittings. To maintain its horizontal alignment, the assembled manifold is wired to a straight piece of hardwood or aluminum angle bar. Inserted into each of the manifold outlets and retained by a plastic compression nut is a short piece of brass stock with a 5/32-inch longitudinal bore. These fittings were carefully reamed to make them as nearly equal in discharge rate as possible.

Four six-inch diameter plastic funnels are supported by the stand's third shelf located below the manifold. These funnels serve as mixing chambers (Figure 2). Each one is provided with a plastic standpipe ⅜-inch in diameter and 1½ inches long. Each funnel receives reservoir water from one of the manifold outlets plus material from one of the chemical metering bottles. The water from the manifold outlet impinges on the wall of the funnel at an angle from the vertical adjusted to impart maximum swirl. The free end of the outlet hose from each of the metering bottles is loosely secured to its corresponding manifold outlet and the two streams become confluent as they enter the mixing funnel. Thorough mixing of the swirling fluids is brought about by the stand-pipe which temporarily retains them in the funnel.

The mixing funnels empty into four six-foot sheet metal V-troughs approximately 1¾ inches deep. The closed upper ends of the troughs are supported by a notched bar on the front of the stand. The lower ends of the troughs rest on a similar bar extending between independent wooden uprights. Each end of the lower support

Fig. 2.—Mixing funnels for simulated stream tests with insecticides.

bar is adjustable for height. The bar, therefore, like the stand, may be levelled to equate velocity of flow in the troughs and by raising or lowering the bar, the velocity may be regulated. Each trough is lined first with a strip of polyethylene sheeting of 4 mils thickness and on top of this a strip of brown wrapping paper. The two strips are creased down the center, fitted into the trough and together are secured by small spring clips. The paper provides a surface to which the blackfly larvae can readily attach, and because it tends to wrinkle when wet, creates a desirable turbulence. By simply discarding both liners after each test all washing of troughs is eliminated. A flat-bottom circular sieve lined with 84 x 100 mesh nylon cloth is fitted into a one-pint plastic box (home freezer container) and placed under the lower end of each trough. The sides of the box slope inward slightly and this keeps the rim of the sieve above that of the box. In this way larvae which detach during a test are retained in a pool while the flow of water is continuous and unimpeded.

Delivery rates from the four reservoir manifold outlets averaged 1790 ml. per minute. Variation in mean delivery rates between the outlets did not exceed 40 ml. per minute. The insecticide metering bottles averaged 431.3 ml. per minute with a maximum variation in mean delivery rate between the bottles of 15.5 ml. per minute. The combined flow in each of the troughs thus averaged 2221.3 cc. per minute (=0.59 gallon). Since the final insecticide concentrations to which larvae were exposed during field operations were seldom more than one part per million, any error introduced by using average delivery rates in making calculations is negligible. For example, the greatest possible variation in final concentrations of chemical in the troughs would occur if by chance the bottle delivering the lowest rate were coupled with the manifold outlet delivering the higest rate while at the same time the bottle with the highest delivery rate were coupled with the outlet having the lowest. Even in these circumstances the range of concentrations to which the larvae would actually be exposed as a result of averaging delivery rates in calculating the amount of chemical for a 1.0 p.p.m. concentration is only 0.98 to 1.02 p.p.m.

The adequacy of mixing obtained with the funnels described above was investigated with a Bausch & Lomb colorimeter, using green food coloring. A light source of 6300 Å was used, since the coloring registered its maximum absorption at that frequency. In a closely simulated field operation, dilute food coloring was fed into a mixing funnel along with water from the reservoir tank. Replicate samples were collected from the lower end of the trough at one minute intervals and the colorimeter was employed to check for differences in color intensity. There was no indication of significant variation in the concentration of the final solution with time. A similar test was carried out to determine whether there were differences in uniformity of mix at the upper and lower ends of the trough. Samples were taken in pairs from the top and bottom of the trough and compared in the colorimeter. No evidence was seen that mixing was not uniform and complete when the two solution components left the funnel. The performance of the mixing funnels was rated entirely satisfactory.

In our field operations thus far, only mature larvae of *Simulium pictipes* have been used. They frequently occur in conspicuous dense masses on flat rock covered by a thin sheet of fast-moving clear water. Experience has shown that they withstand handling very well. They are easily collected by gently dislodging them from their place of attachment with one hand and catching them in a sieve held in the other as they are swept downstream. An equal number of larvae are established in the water running in each of the troughs. When it is certain that the required number is well attached, the chemical is admitted to the troughs. At the conclusion of a test, those larvae remaining attached in the troughs are dislodged with a small camel's-hair brush and collected in the nylon-lined sieves. Each nylon square is formed into a bag holding the larvae from one trough plus an identifying label. The neck of each bag is closed by twisting a pipe cleaner around it and the free ends of the pipe cleaner are used to wire the bags to the mesh floor of a small ¼-inch hardware cloth cage. Thus confined, the larvae are returned to the stream from which they were collected to await twenty-four and forty-eight hour mortality counts.

Field trials of this method of larvicide testing have been very satisfactory. Preliminary results including a comparison with jar tests are reported by Travis and Wilton (1965). Insecticide investigations constitute only one area in which the equipment described above will prove to be a useful tool. Studies of the bionomics and ecologies of numerous small lotic organisms should be able to employ such an approach profitably.

SUMMARY.—A procedure is described in which larvae of *Simulium pictipes* were exposed to insecticide formulations in stream water running in small paper-lined troughs. All equipment used is portable and was set up near a suitable source of larvae in the field. Larvae for testing were established in the troughs and the insecticide, thoroughly mixed with the stream water, was metered into the troughs for a standard exposure period. Concentrations to which the larvae were exposed seldom exceeded 1.0 p.p.m. The means of achieving the necessary constant rate of flow in the troughs and uniform dispensing of the insecticide formulations are described. Following treatment, the larvae, confined in nylon bags, were returned to the stream from which they were collected for 24- and 48-hour observations. Advantages of the present testing procedure over several others previously reported are discussed.

References

GJULLIN, C. M., COPE, O. B., QUISENBERRY, B. F., and DU CHANOIS, F. R. 1949. The effect of some insecticides on blackfly larvae in Alaskan streams. Jour. Econ. Ent. 42:100–105.

JAMNBACK, H. 1962. An eclectic method of testing the effectiveness of chemicals in killing blackfly larvae (Simuliidae: Diptera) Mosq. News 22:384–389.

LEA, A. O., JR., and DALMAT, H. T. 1954. Screening studies of chemicals for larval control of blackflies of Guatemala. Jour. Econ. Ent. 47:135–141.

MUIRHEAD-THOMPSON, R. C. 1957. Laboratory studies on the reactions of *Simulium* larvae to insecticides. Amer. Jour. Trop. Med. Hyg. 6:920–934.

TRAVIS, B. V., and WILTON, D. P. 1965. A progress report on simulated stream tests of blackfly larvicides. Mosq. News. 25:112–118.

WORLD HEALTH ORGANIZATION. 1954. Expert committee on Onchocerciasis. First Report. Geneva.

MOSQUITO CONTROL AT NASA'S MISSISSIPPI TEST OPERATIONS

FREDERICK W. HARDEN

Entomologist, General Electric Company, Mississippi Test Support Operations, Bay St. Louis, Mississippi

The mosquito control program at NASA's Mississippi Test Operations is unique among organized mosquito control programs in this area for several reasons: First, the area under control has no permanent residents, only transient employees of NASA and its contractors, many of whom have never lived in an area with a serious mosquito problem. Secondly, the program is under the supervision of a non-governmental agency, the General Electric Company, which is NASA's support contractor at M.T.O.

Mississippi Test Operations consists of two areas, the Fee Area and the Buffer Zone.

The Fee Area consists of approximately 13,500 acres of pine forest and hardwood swamps. This is the area where all work activity will be concentrated.

The Buffer Zone is an unpopulated area consisting of approximately 128,500 acres. The north and south-central portion of the Buffer Zone is made up of flat, poorly drained pine forest. Southeast and bordering the Fee Area is a 20-square-mile pine and hardwood swamp referred to as the "Devil's Swamp."

The Pearl River Swamp acts as the western boundary of the Fee Area. Beginning at the northwest corner of the Buffer Zone, it is already some 5 miles wide and extends 20 miles south to the Gulf of Mexico at Lake Borgne, at which point it is approximately 18 miles wide. North of Highway 90 it is primarily a very dense hardwood swamp, criss-crossed by the three branches of the Pearl River and numerous small bayous and streams. At a point just north of Highway 90, the tree swamp begins a transition into a grassy salt marsh. Within 20 miles of the Fee Area there is approximately 50,000 acres of grass salt marsh and some 50,000 acres of river flood plain tree swamps.

During most of 1963, salt-marsh mosquitoes, *Aedes sollicitans* and *Aedes taeniorhynchus,* and the flood-water mosquito, *Aedes vexans,* were present in astronomical numbers. *Aedes sollicitans* were the primary problem, however. Head nets and mosquito repellent had little effect. The Corp of Engineers estimated that work efficiency at M.T.O. due to mosquitoes was 25 percent less than that which could be normally expected, and in addition, some crews left their jobs.

With the mosquito annoyance so severe, it was decided to employ airplane spraying in July of 1963, due to the fact that no organized mosquito control program was in existence on the site. During the period of July 17 through 26, malathion