EVALUATION OF NALED APPLIED AS A THERMAL FOG AGAINST *CULICOIDES FURENS* (DIPTERA: CERATOPOGONIDAE)[1]

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ABSTRACT. Naled/diesel oil (1:99), applied as a thermal fog, was tested against the biting midge *Culicoides furens*. The insects were confined in small cages suspended at 4 heights on poles at progressively greater distances from the fog release point. In terms of population survival 24 hr after treatment, a parabolic equation accurately described the regression of percent survival on distance from the release point. If 10% survival is considered as the maximum acceptable, then the equation predicts adequate control up to 19.6 m (64.3 ft) from the fog release point.

INTRODUCTION

Biting midges (*Culicoides* spp.), especially *Culicoides furens* (Poey), *C. barbosai* Wirth and Blanton and *C. mississippiensis* Hoffman, are important pests of man in the heavily populated and economically important coastal areas of Florida (Linley and Davies 1971). Other species are the cause of similar problems in many other parts of the world (Linley 1976). For many years, concern for the environment has restricted the direct application of pesticides to the swamps and marshes where these insects breed. Control, where attempted, has been confined to the adult stage, usually in conjunction with concurrent efforts to reduce mosquito populations. Thermal fogging and ultra-low-volume (ULV) spraying have traditionally been the two methods applied, although ULV has, in recent years, almost entirely supplanted thermal fogging as the method of choice for mosquito control.

Despite the annoyance created by midge populations and the interest of control agencies in providing effective relief, relatively few efforts have been made to evaluate adulticidal methods under field conditions. In the laboratory, wild-caught insects have been used for evaluation of various insecticides in wind tunnel experiments (Kline et al. 1981, Floore 1985). Two recent field studies, by Giglioli et al. (1980) and Haile et al. (1984) have tested, respectively, the effectiveness of ULV fenitrothion against *C. furens* and *C. barbosai* in Grand Cayman, and of ULV naled against *C. hollensis* (Melander and Brues) in South Carolina. However, no data obtained to date allow comparison of thermal fogging as opposed to ULV methods for control of *Culicoides* under field conditions. Also, it is of interest to know the degree of midge control obtained from routine adulticidal treatment directed primarily against mosquitoes. Accordingly, this paper reports the first of a series of tests to evaluate the use of different application methods for control of adult biting midge populations.

MATERIALS AND METHODS

Culicoides furens adults (females) were collected by aspiration at a site on Hutchinson Island, about 8 km south of Ft. Pierce, Florida. The insects were kept and transported in 473 ml (1 pt.) ice cream cartons with nylon gauze lids supporting small wads of cotton soaked in 10% sucrose. For exposure during test, midges were placed in specially built cages consisting of an exposure and postexposure chamber separated by a closable (sliding) aperture (Fig. 1A). The exposure end consisted of a 3 cm cubical stainless steel screen cage (15.7 mesh/cm, Tetco Inc., Elmsford, NY) sealed at the edges with paraffin wax and at the bottom to a plastic lid. Between this lid and a similar one capping the postexposure chamber was a rectangular plastic slider (3.5 x 11 cm) adjustable to open or closed positions (Fig. 1A). The slider, fitted at one end with a suspension hook, was retained between small plastic guides contact cemented between the two lids. The postexposure chamber was made from a cylindrical clear plastic container 4.5 cm diam. and 7.5 cm long. A 3 cm diam. hole in the bottom, covered with stainless steel mesh, allowed through passage of air when it was necessary to blow the insects from one chamber to the other. The chambers worked well during the experiment. Their only disadvantage is that they are somewhat delicate and must be handled carefully.

The test was conducted in Sarasota County, at Siesta Public Beach, in an area of predominantly open terrain, with occasional bushes (Fig. 1B). The cages were suspended from hooks (Fig. 2A) set at heights of 15, 46, 91 and 183 cm (6, 18, 36, 72 in.) on poles implanted in the ground. Poles were spaced at intervals of 7.6 m (25 ft) in two lines 3 m (10 ft) apart, with the first two poles 3 m from the line of release of the fog (Fig. 2B). Two control cages were hung from vegeta-

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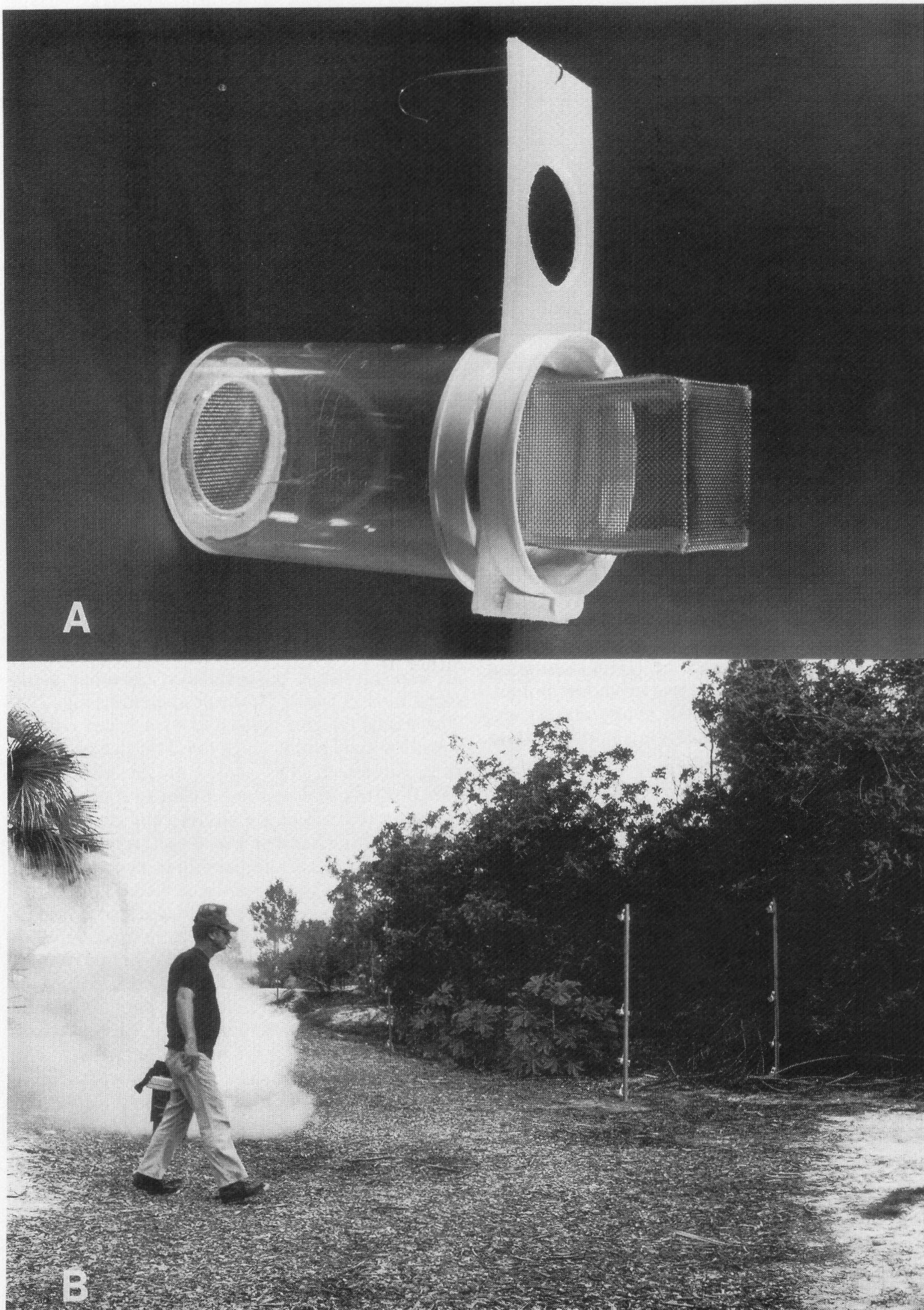

Fig. 1. A, cage used to confine *Culicoides furens* adults during test; exposure chamber to right, postexposure chamber to left. B, method of fog release; first 2 poles with cages in position at right.

tion at a height of about 91 cm, 50 m away and upwind of the fog release point. Beginning at about 0600 hr, in the laboratory, the adult *Culicoides* were anesthetized with CO_2 and transferred quickly (*Culicoides* recover extremely rapidly from CO_2 anesthetization) to the mesh exposure chambers. Chambers received between 6 and 50 insects, the numbers being unequal because of insufficient time to count insects prior to recovery from anesthetization. The cages were then carried out to the field site and suspended from the poles. At 0745 hr (sunrise + 71 min) fog was dispensed (Fig. 2) about 61 cm (2 ft) above ground along a line 30 m (100 ft) long perpendicular to the pole lines. A London Turbo Hand Fogger (London Fog Co., Crystal Bay, MN) was used, held by an operator moving at about 55 m/min (2 miles/hr). The insecticide mixture consisted of naled (Dibron 14) concentrate/diesel fuel 1:99, dispensed at a rate of 19–23 liters (5–6 gallons)/hr. Air movement during the test was almost ideal; fog drifted along the pole lines at about 70 m/min (approximately 2.5 miles/hr).

Cages were left in place for 15 min after fog release, then taken down and the insects blown into and confined in the postexposure chambers. Back at the laboratory, the cages were laid in large Plexiglas® boxes containing damp paper towelling and mortality recorded at 1, 3, 6 and 24 hr posttreatment.

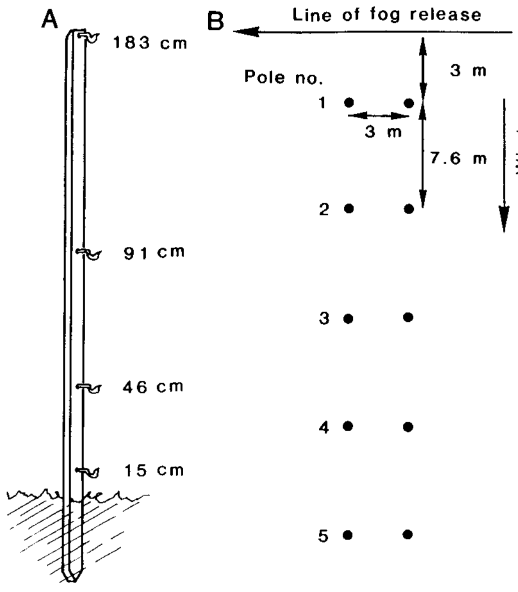

Fig. 2. A, pole with hooks for suspension of cages at 4 heights. B, layout of pole lines relative to line of fog release and prevaling wind direction.

RESULTS

The control cages were very similar, showing (combined data) no mortality at 1 and 3 hr posttreatment, then 5.5% at 6 hr and 14.8% at 24 hr. Where appropriate, Abbott's formula has been used to correct the data prior to further analysis.

With one exception, results from the two pole lines were very similar and data from replicate cages have been combined for analysis. The only inconsistency was that at the 183 cm height on poles 1 and 2 of one of the pole lines (nearest the fog release point, Fig. 2B) mortality was relatively low compared to the other replicate at 1 and 3 hr posttreatment. This inconsistency was caused by unequal upward disperal of fog as it moved down the pole lines. The effect does not alter the main conclusions of the study, but we mention it to emphasize that some "patchiness" may occur in the effect of a given treatment owing to local air currents.

Since the data provided information on the effects of cage height, distance from fog release point and time after release, they have been plotted isometrically in time blocks (Fig. 3). Observations at 3 hr posttreatment have been omitted as superfluous. Percentage survival rather than mortality is depicted because in assessing treatment effect it is more immediately relevant to measure the surviving population, which retains its nuisance potential.

At 1 hr after treatment (Fig. 3) no *C. furens* were alive at the 15 cm cage elevation at 3 and 10.7 m from the release point and very few (<7%) at the 46 and 91 cm elevations. As less fog reached the highest cage, especially in one pole line, survival was considerably greater at this level. Up to 1 hr the greatest effect was noticeable out to 10.7 m; survival was somewhat reduced but still substantial (>62% at all heights) at 18.2 m from the release point, and very high (>85%) at all heights beyond this distance. With the subsequent passage of time, as shown in the time blocks for 6 and 24 hr (Fig. 3), the lethal effect gradually spread both upward and along the pole lines. By 6 hr after treatment very few *C. furens* were still alive out to 18.2 m at all cage elevations except the highest, and almost all were dead at the highest level on the first pole (Fig. 3). Eighteen hours later (24 hr), no insects remained alive on the poles at 3 m and none, except a few (<13%) at the highest elevations, on the poles at 10.6 and 18.2 m. Beyond 18.2 m, some midges survived at all heights, although the maximum at 25.9 m at any level was 27%, with somewhat higher values at 33.5 m, where the maximum survival was 77% at the top cage elevation (Fig. 3).

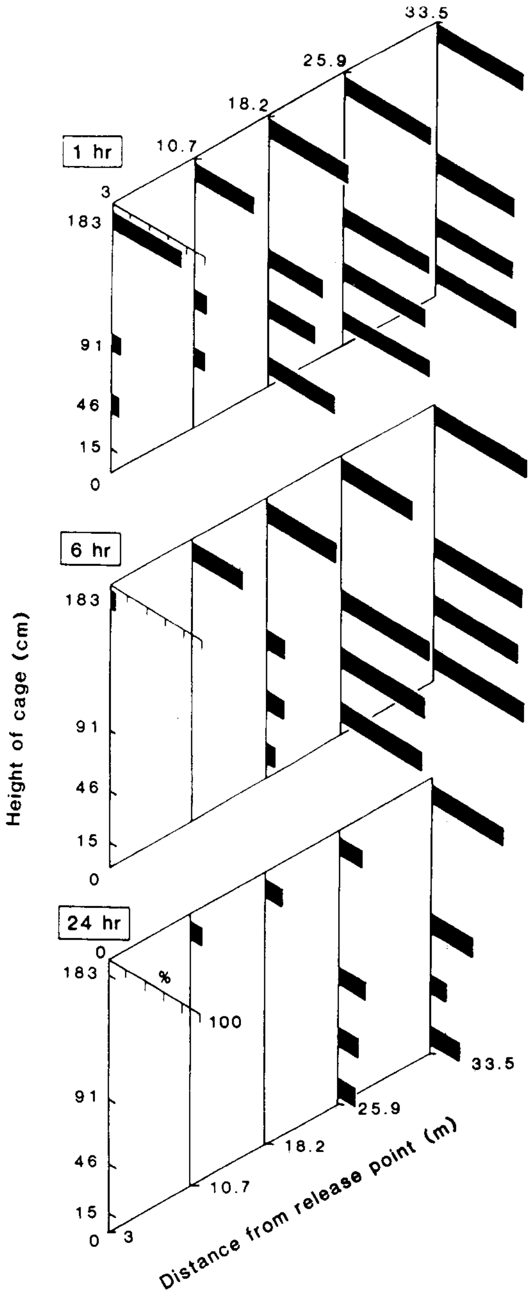

Fig. 3. Isometric plots of percent survival of *Culicoides furens* adults (data from both pole lines combined) at 1, 6, and 24 hr after treatment.

DISCUSSION

It is useful, initially, to consider how the use of caged insects may have affected the results. The steel mesh used to fabricate the exposure chambers presented 54.8% open area to fog droplets, so that a fairly large proportion presumably impinged on the exterior of the mesh and did not enter the cage. Droplets that passed through the first mesh into the cage may, however, have settled on the interior. Thus, chemical could have contacted crawling midges during the 15 min posttreatment period prior to transfer into the postexposure chambers. Increased survival caused by interception of chemical on the mesh exterior was probably offset by its settlement on the interior.

Although a large proportion of the *C. furens* remained alive beyond 10.7 m at 1 hr and beyond 18.2 m at 6 hr after treatment, relatively few survived to 24 hr (Fig. 3). Insects that did not die within a short time had, nonetheless, been lethally affected and their behavior might presumably have been altered for many hours before death. The desired control objective would be achieved if the affected *Culicoides* were deterred from biting until the time of death. Thus, despite the survival of midges for many hours at the greater distances from the release point, good control would be achieved out to 18.2 m and there would be some relief even at 33.5 m. While it is possible that sublethally poisoned midges may cease to seek a host, we have assumed that the behavior of midges still surviving after 24 hr was not significantly affected and that they would remain part of the biting population. On this assumption, the data for 24 hr after treatment can be used to assess the relationship between level of control and distance from the release point. This is a general estimate for which it is best to combine data from all heights (both pole lines) to show the change in percent survival with distance (Fig. 4). The data are accurately ($r^2 = 0.98$) described by the par-

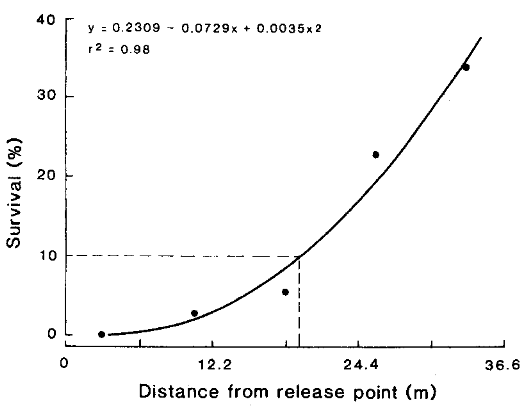

Fig. 4. Relationship of percent survival of *Culicoides furens* adults (data from both pole lines and all cage heights combined) to distance from fog release point at 24 hr after treatment.

abolic regression model (Fig. 4), from which the distance equivalent to a given percent survival can be estimated. The level of survival commensurate with human comfort is to some extent a matter of opinion and will depend also on the numbers of midges initially present. Giglioli et al. (1980) considered that 1 bite/min was equivalent to complete shirtless comfort, while Linley and Davies (1971) preferred a more conservative estimate of 1 bite/12 minutes. We will assume here that 10% survival can be taken as a working figure representing good control. Thus, from the equation in Fig. 4, the distance from the release point equivalent to 10% survival is about 19.6 m (64.3 ft). Other survival percentages of possible interest are 1, 5, 20 and 30%, which occur at about 8.6, 14.6, 26.3 and 31.5 m, respectively. Using the biting tolerance figure given by Giglioli et al. (1980), this means that a hand-held fogger will provide acceptable control out to about 20 m (66 ft) from the release point when the pretreatment biting rate is 600/hr. This is not, however, a particularly heavy biting rate compared, for example, to the 1,216 *C. furens*/hr collected from one leg only at a site in the Caribbean (Linley and Davies 1971). From the regression equation (Fig. 4), it is easy to calculate the effective range of the hand-held fogger (using naled) with respect to attaining the Giglioli et al. (1980) tolerable biting rate from different pretreatment population levels.

Naled was selected for test because of its current importance to mosquito control interests. However, it is not the most effective compound for use against *Culicoides*. In fact, according to the results of wind tunnel tests, naled was the third most ineffective of seven (Kline et al. 1981) and the most ineffective of nine (Floore 1985) chemicals evaluated. Pyrethroid compounds (resmethrin, permethrin, phenothrin) were substantially more effective and presumably would to some extent extend the range of control in thermal fog applications. As regards the general usefulness of thermal fogging as a control measure for *Culicoides*, the hand-held machine used here dispensed only 19–23 liters (5–6 gallons) of insecticides/hr, as compared to 114–151 liters (30–40 gallons)/hr put out by larger, vehicle-mounted machines. The range of control would perhaps be greater with a larger unit, although the greater dispensation rate would be offset to a large extent by the normally greater travel speed of the vehicle.

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