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CHEMICAL CONTROL OF MOSQUITOES IN CANADA [2]

Riassunto. — Per lottare, al Canadà, contro le grandi popolazioni di *Aedes* nelle regioni non-agricole, è necessario sottoporre vaste aree alle polverizzazioni e agli aerosol adulticidi.

Un certo numero di generatori di aerosol sono stati sperimentati. La TIFA è di largo uso; una dose di 0,3 libbre di DDT per 100 yards di fronte distrugge gli insetti in un raggio di 400 yards sottovento. Il metodo più efficace consiste nel vaporizzare nell'aria del DDT in soluzione oleosa. L'aeronave « Dakota » in uso (DC 3 o C-47) è caricata con 500 galloni imperiali di soluzione al 10% per spruzzare ad ogni volo una zona di 3.400 miglia quadre, in ragione di 0,22 libbre di DDT per acre. Un dispositivo di spazzole rotative, trascinato dal peso, emette un getto d'un diametro medio di 180 micron che, nelle foreste di abeti del nord, stermina il 99% delle zanzare. L'autore descrive i metodi da seguire per predisporre ed attuare un piano di operazioni di polverizzazione su larga scala.

Nel Canadà, l'importanza del problema delle zanzare riguarda più la gravità dell'attacco che la trasmissione delle malattie (7,9). Per la maggior parte del suo spazio questo paese consta di pianure dai laghi, mari e stagni innumerevoli. E' nella zona nord di transizione fra la foresta e la tundra che il problema si pone con la maggior gravità.

Résumé. — Pour lutter, au Canada, contre les grandes populations d'*Aedes* dans les régions non agricoles, il est nécessaire d'appliquer à de vastes superficies, par pulvérisation ou par sondage, des aérosols adulticides.

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On a expérimenté un certain nombre de générateurs d'aérosols. Le TIFA est largement utilisé; une dose de 0,3 livre de DDT pour 100 yards de front détruit les insectes dans un rayon de 400 yards sous le vent. La méthode la plus efficace constitue à vaporiser dans l'air du DDT en solution huileuse. L'aéronef Dakota, que l'on emploie (DC 3 ou C-47), est chargé de 500 gallons impériaux de solution à 10% pour vaporiser à chaque vol une zone de 3.400 milles carrés, à raison de 0.22 livre de DDT par acre. Un dispositif de brosses rotatives, entraîné par la pesanteur, émet un jet d'un diamètre moyen de 180 microns qui, dans les forêts de sapins du nord, extermine 99% des moustiques. L'auteur décrit les méthodes à suivre pour établir et exécuter un plan d'opérations de pulvérisation à grande échelle.

Au Canada, l'importance du problème des moustiques se rapporte plutôt à la gravité de l'attaque qu'à la transmission de la maladie (7,9). Sur sa plus grande étendue, ce pays est une pénéplaine, aux lacs, mares et étangs innombrables. C'est dans la zone nord de transition entre la forêt et la toundra que le problème se pose avec le plus de gravité.

Summary. — To combat the large *Aedes* population in the non-agricultural areas of Canada, it is necessary to apply aerosols, destroying the adult insects, to enormous areas by spraying or boring.

Experiments have been carried out with a number of aerosol generators. TIFA is widely used; a dose of 0.3 lb. DDT for every 100 yards of front destroys insects within a range of 400 yards downwind The most effective method consists in vaporizing an oily solution of DDT in the air. The Dakota aircraft employed (DC-3 or C-47) carries 500 gallons of 10% solution in order to vaporize a zone of 3,400 sq. miles on each flight, at the rate of 0.22 lb. DDT per acre. An arrangement of rotatory brushes, operated by gravity, throws out a jet of an average diameter of 180 microns which, in the northern pine forests, exterminates 99% of the mosquitoes. The author describes the methods to be adopted in order to establish and execute large-scale spraying operations.

In Canada, the importance of the mosquito problem is related more to the severity of attack than to transmission of disease (7.9). Over the greater part of its extent, this country is a peneplain, with innumerable lakes, pools and ponds. It is in the northern zone of transition between forest and tundra that the problem appears at its most serious.

Zusammenfassung. — Damit man die grosse Anzahl von *Aedes* in dem unbebauten Gegenden Kanadas bekämpfen kann, muss man auf sehr breite Oberflächen Adultizid-Aerosol entweder durch Nebulisierung oder durch Bestreuung verwenden.

Man hat eine gewisse Anzahl von Aerosol-Erzeuger geprüft.

TIFA ist sehr verbreitet: eine Dosis von 0,3 Pfund DDT für 100 Yards-Front vernichtet in der Windrichtung die Insekten binnen einen Radius von 400 Yards. Die wirksamste Methode besteht aus einer Öllösungsvaporisation von DDT in der Luft.

Es wird ausserdem «Aeronef Dakota» (DC 3 oder C-47) verwendet; es wird mit 500 « imperial Gallons » 10% Lösung geladen um, bei jedem Flug, eine Oberfläche von 3.400 quadrat Meilen, gleich 0,22 Pfund per Acre, zu bestreuen. Eine Einrichtung von durch Gewicht rotierenden Bürsten bespritzt einen Strahl von 180 Mikron Durchmesser, der in den nördlichen Tannenwäldern 99% der Mücken vernichtet. Der Verfasser beschreibt die Methoden, die man verfolgen sollte, um eine massenhafte Betäubung zu organisieren und durchzuführen.

Die Bedeutung der Mücken bezieht sich in Kanada vielmehr auf die Heftigkeit des Angriffes als auf die Übertragung einer Krankheit (7,9). Im grossen Ganzen ist dieses Land ein Peneplan, mit zahlreichen Seen, Sümpfen und Teichen. Das Problem stellt sich in der Übergangszone zwischen Wälder und Tundren als sehr ernst vor.

In Canada, control of large populations of *Aëdes* spp. in non-agricultural areas requires coverage of extensive areas with adulticide aerosols and sprays. A number of aerosol generators have been tested. The TIFA is widely used; a dosage of 0.3 lb of DDT per 100 yards of frontage gives control for 400 yards downwind. The most effective method is aerial spraying with DDT in oil solution. The Dakota aircraft (DC-3 or C-47) is used, and is loaded with 500 imperial gallons of 10 per cent solution to cover 3.4 square mile per flight at 0.22 lb of DDT per acre. A rotary brush unit supplied by gravity feed emits a spray with a mass median diameter of 180 microns, and gives 99 per cent control in northern spruce forest. Methods of planning and performing a large-scale spray operation are described.

The mosquito problem in Canada is one of severity of attack rather than disease transmission (7,9). The great mass of the country is a peneplain with innumerable lakes, ponds and pools. The problem is worst in the northern zone of transition between forest and tundra, where the predominant cover is spruce (*Picea* spp.). Melting snow in April and May produces standing water, in which a score of species of *Aëdes*, notably *punctor*, *hexodontus*, and *communis*, hatch from their overwintered eggs, pass about three weeks as larvae and three days as pupae, and emerge in vast numbers. Biting rates on exposed forearms range up to 280 a minute, which would theoretically drain a naked man of half his blood in 1-3/4 hours ([4]).

The problem of control is, therefore, to reduce the mosquito population to tolerable numbers around northern settlements, a process somewhat analogous to making a hole in shifting sand. The larger the area treated by insecticide, the longer the control remains effective. Despite testing of other compounds, DDT dissolved in fuel oil remains at present the preferred material for operational use in Canada. The objective is to cover as large an area as possible, as economically and rapidly as possible, killing either the larvae in the pools or the adults by direct contact. The development of methods and the testing of machines has been undertaken since 1947 by the Entomology Division on behalf of and in co-operation with the Defence Research Board, Department of National Defence, which has provided funds and given other assistance in carrying out the work. The Veterinary and Medical Entomology Unit of the Division has conducted the programme; and, since much of the work is seasonal, it has augmented its staff by employing the services of professors and students from the universities during the summer months.

Of the machines operated on the ground, those based on the mist-blower principle, such as the Lawrence Aero-Mist, Buffalo Turbine, Portamist, and Microsol machines, produce fine sprays that control adults and larvae, but their effect is limited to distances within 100 yards downwind of the line of emission; the thermal aerosol machines, such as the TIFA, Dyna-Fog, Bes-Kil, and Swingfog generators, have a considerably larger range; this depends of course on the amount of DDT emitted per unit of frontage, but when 0.3 lb is emitted per 100 yards the effective range is about 400 yards downwind ([3]). The droplet sizes given by the TIFA are represented by a mass median diameter between 10 and 20 microns; larger droplet sizes are produced by the Bes-Kil (a steam generator), and smaller sizes by the Swingfog and Dyna-Fog (both jet generators). The Bes-Kil is better adapted to open country than woodland, the Dyna-Fog gives excellent results in woods, and the hand-portable Swingfog is a very effective unit handicapped only by a low emission rate. The TIFA is the most generally used machine [5], and is employed by the Canadian Army to protect their camps. Recently the use of air-mix nozzles on machines such as the Husman sprayer and the Alaska aerosol sprayer has given sufficient true aerosol output to achieve long range without the use of heat. All these ground-operated machines, however, depend on the existence of roads or trails for their usefulness.

For the control of mosquitoes in the great bulk of the territory, more than a quarter of a mile from roads, aerial spraying is the only possible method. Although Cub, Stearman, and Norseman aircraft, and even helicopters, have been used by commercial concerns in the southern settled regions, the Dakota (also called DC-3 or C-47) aircraft is the one employed in the large-scale spraying operations that in the last five years have been developed in co-operation with the Royal Canadian Air Force. This twin-engined, easily maintained plane-of-all-work can safely carry 2½ tons of insecticide and has a cruising speed of 150 miles per hour. The spray solution is carried in two 275-gallon tanks (emergency fuel tanks from the Mitchell B25-J bomber) installed on cradles in the fuselage and connected to a common outlet.

Although a boom-and-nozzle assembly and pumping system has been developed for this aircraft in both Alaska and Canada, and has given excellent results, one phase of developmental research has concentrated on simple apparatus to be installed for only one month in the year. The simplest is a straight emission pipe, 2½ inches in diameter, projecting vertically 18 inches below the fuselage, cut off at 45° facing rearwards, and fed by gravity flow through a quick-acting valve from the tanks [8]. When the spray is emitted into the air at 2.25 gallons per second, its forward momentum (imparted to it by the aircraft) upon meeting the comparatively stationary air below shatters it into a spray of droplets the mass median diameter of which has been determined to be 340 microns, the largest droplets being 600 and the smallest five microns.

The aircraft is flown along parallel lines 200 yards apart, utilizing the cross wind, or cross-wind component of the existing wind (*), to spread the spray across the 200-yard-wide swath or even farther. The largest droplets in the spray, falling fastest, reach the ground closest to the line of flight and the progressively smaller droplets, falling more slowly, reach the ground progressively farther downwind. The higher

(*) $T \cos \Theta$, where T is the speed of the wind, and Θ the angle by which it diverges from the cross-track direction the aircraft and the greater the speed of the cross wind, the wider the swath. Thus it is the height-wind *HU* product that determines the swath width. The greater the *HU* product, the broader the swaths, the more they overlap, and the more even the deposit resulting. Since very high *HU* products involve spraying from considerable heights and the risk of evaporation of droplets in their fall the height-wind product selected was 1,500 feet-mile/hour, e.g., a height of 150 feet for a 10 mile/hour cross wind, and 300 feet for a 5 mile/hour cross wind. It must be observed that these relationships governing the fall of droplets obtain only when there is no upward convection of air, as in the evening or early morning, or on days of heavy overcast. Convection may be measured as the gradient between the air temperatures at 1 metre and at 2 metres above the ground level.

With this method, applications of 4 per cent DDT in fuel oil solution at 0.25 lb of DDT per acre to breeding pools over a total of 68 square miles in Labrador, northern British Columbia, and Yukon Territory gave an average of 91 per cent reduction in numbers of the larvae. Subsequent adult populations at the stations so protected were approximately half of those in unsprayed areas ([8]). Since this is not sufficient protection, applications against the adults by the same method were tested, the same rate on a total of 66 square miles giving an average of 85 per cent reduction in numbers of the adult mosquitoes ([6]).

Efforts were then directed to improving the performance of adulticide spraying by increasing the atomization, since a finer spray would be more effective, avoid the wasteful large droplets, and allow spraying at lower height-wind products. First the emission pipe was bent rearwards, occluded, and then perforated with holes that emitted into an air-scoop. This did not improve the atomization owing to the formation of large droplets on the rearward edge of the air-scoop itself, the resultant spray having a mass median diameter of 400 microns. Then a single rotary-brush unit was substituted and affixed to the pipe ([2]); this proved successful and gave a much finer spray, with a mass median diameter of 180 microns.

The rotary-brush unit is one of a series made commercially, and consists of a sheet of aluminium discs fringed with a brush of fine wire and sandwiched between a 10-inch disc of sheet aluminium and a hub-cap. This sheaf is rotated on a horizontal shaft by a wooden propellor 23 inches in diameter and with a pitch of 50°, a steepness adjusted

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([*]) Independent Crop Dusting, Inc., Campbell, California, USA.

to the speed of the aircraft to rotate it at approximately 2,500 r.p.m. Five brush discs were used in the sheaf, three 10-inch brushes of coarser wire alternating with two 8-inch brushes of finer wire. When 10 per cent DDT solution was used, the emission rate was 1.05 gallons per second. The aircraft was flown along parallel lines 300 yards apart, at a set height of 100 feet, the dosage of DDT being 0.22 lb per acre. An average of 98.7 per cent reduction of adult mosquito population was obtained over a range of types of spruce forest. Excellent overlap of this finer spray was obtained, despite the greater interval between lines of flight and the lower height-wind product.

By this method under northern Canadian conditions a Dakota aircraft may take off with enough insecticide (500 gallons) to treat 3.4 square miles of forested area, giving almost 100 per cent reduction of adult mosquito population. With 20 per cent DDT concentrate, and a three-brush assembly emitting at 0.58 gallons per second, the aircraft can carry enough insecticide to treat 6.1 square miles and give an average reduction, as determined by experiment, of between 96 and 97 per cent.

Mosquito control in the northern settlements of North America is thus reduced to an adulticide spraying operation covering 10 to 20 square miles that may be accomplished by 3 to 6 flights of a Dakota temporarily fitted for the purpose. The DDT is freighted into the nearest airfield as 30 per cent concentrate in 45-gallon drums. It is diluted with domestic fuel oil in an oil tender truck (oil furnaces are now widely used in Canada), which then pumps it into the tanks in the aircraft. The rest is cartographical intelligence. On a map, preferably at 1 inch to the mile, the director of the operation plots the individual spray runs, bearing in mind that each 500-gallon load of 10 per cent DDT solution is sufficient for 480 seconds of emission, equivalent to a total of 36,000 yards (approximately 20 miles) of flight at 150 miles per hour (74 yards per second). The set of parallel lines makes the plot for one flight. A road, river bank, lake shore, or railroad running approximately at right-angles to the line of flight is used as the starting line, and along it stakes are placed at 300-yard intervals to serve as positions for the marker. Nylon cloth panels, dyed with the luminescent pigment « arc yellow », furnish excellent markers. The aircraft is flown over the marker on a given compass bearing, and the valve is opened at the marker or at an agreed distance from it; it is closed again after a given number of seconds. Then the marker is moved to the next stake by the ground crew, and the next line is flown in the same way. The lines are flown at right-angles to the prevailing wind; almost always there is enough cross-wind component to spread the swath. One extra starting point is put in; the end point that is downwind at the time of spraying is not used. A detailed map or tracing of the plot to be treated during the flight is given to the pilot, who may have radio communication with the gound party, although that is now no longer essential. The plots are arranged so that together they cover the whole area.

The adulticide applications are made in June at a time when the peak of emergence has not quite been reached. In many instances the mosquitoes may not become a problem again that summer; in others the control may last for three to four weeks; certain heavily forested regions may require a second spray a week later. When the rotary brush is used, these aerial sprayings may effect a reduction in numbers of adult black flies as high as 90 per cent, but the area is likely to be quickly reinfested from untreated areas. Larvae of black flies are practically eliminated from streams running through the sprayed area and for several miles downstream. Tabanids (horse flies and deer flies) are not affected. Beneficial insects, in general, do not seem to be seriously affected, and there is no detectable effect on fish or wild-life at the 0.25 lb per acre dosage employed. The aerosol treatments mentioned at the beginning of this paper gave no discernible reduction in the activities of the other flying insects, including other adult Diptera, and the effect on black flies was apparently negligible. It is worthy of note that no acquired resistance to DDT by the *Aëdes* mosquitoes in the treated areas has yet been detected in Canada.

Of the many people who have been associated with this work, the author would like to single out Dr. C. R. Twinn, Head of the Veterinary and Medical Entomology Unit, as director and co-ordinator of biological and control studies of biting flies in Canada, and to thank him *inter alia* for providing the majority of the lantern slides used to illustrate this paper.

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