EFFECT OF TEMPERATURE ON THE INSECTICIDAL ACTION OF MOSQUITO LARVICIDES

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Most of the investigations to determine the effect of temperature on the toxicity of chemicals to mosquitoes have been made with DDT. Lindquist *et al.* (1946) found that DDT was more effective against adults of *Anopheles quadrimaculatus* Say and *Culex quinquefasciatus* Say at 70° than at 90° F. Richards and Cutkomp (1946) reported that DDT in acetone suspension (1 part of insecticide to 1 billion parts of water) was more toxic to larvae of *Aedes aegypti* (L.) at 15° than at 28° C. Fan, Cheng, and Richards (1948) found that in insects a negative temperature coefficient was obtained with a low concentration of DDT, that a positive coefficient was obtained with a high concentration, and that DDT was more toxic at low temperatures than at high temperatures.

Several control agencies have reported that the temperature prevailing at the time of treatment appears to affect the efficiency of some insecticides. To obtain information on the toxicity of several larvicides at high and at low temperatures, a series of laboratory tests were conducted at the Corvallis, Oreg., laboratory of the Bureau of Entomology and Plant Quarantine with larvae of several species of mosquitoes. The materials tested were DDT, TDE, methoxychlor, the fluorine analog of DDT (1,1,1-trichloro-2,2-bis(*p*-fluorophenyl)ethane), lindane, benzene hexachloride (12.8 per cent gamma isomer), toxaphene, chlordane, parathion, heptachlor, dieldrin, and aldrin. All tests were made at 63° and 93° F., with a variation of 2° to 3°, against fourth-instar larvae of floodwater *Aedes* (equal numbers of *A. vexans* (Meig.) and *A. sticticus* (Meig.)).

At the beginning of the investigation all the larvicides were tested at only one concentration against a mixed culture of *Culex* larvae containing 5 to 8 per cent of *C. stigmatosoma* Dyar and about equal numbers of *C. pipiens* and *C. tarsalis* Coq. Later a nearly pure culture of *C. stigmatosoma* was found, and five of the larvicides were tested at several concentrations against this species. Nine of the larvicides were tested at several concentrations against *Aedes nigromaculis* (Ludlow), an abundant species in many irrigated areas. The *Culex* and the *A. nigromaculis* larvae were tested at a minimum of 68° F. because they are warm-weather species; if they are held below 65° for an extended period their development is seriously retarded and their mortality high.

All the larvicides were dissolved in acetone. The desired concentrations were obtained by placing different quantities of the acetone solutions in containers filled with 300 ml. of water. Twenty fourth-instar larvae were placed in each container. Each test was replicated at least three times, usually six to eight times, and two or more lots of larvae were used in each test. *Aedes* larvae were grown from eggs in soil taken from breeding areas. *Culex* larvae were collected as small larvae from nearby ponds, and reared to near fourth instars at 80° F. in the laboratory. About 20 hours before the larvae were to be used they were placed in cabinets adjusted to the same temperature at which the tests were to be made. Water containing the acetone solutions was brought to the required temperatures before the larvae were introduced. Mortality counts were made after 24 and 48 hours, but only the 48-hour counts are given in Table 1.

Discussion of Results.—The effectiveness of several of the larvicides varied considerably at the different temperatures. DDT was consistently more effective against all

TABLE 1.—Effect of temperature on toxicity of larvicides to mosquito larvae. Per cent mortality in 48 hours after treatment.

Larvicide	Concentration p.p.m.	Floodwater Aedes 63° F.	Floodwater Aedes 93° F.	Aedes nigromaculis 68° F.	Aedes nigromaculis 93° F.	Mixed Culex 68° F.	Mixed Culex 93° F.	Culex stigmatosoma 68° F.	Culex stigmatosoma 93° F.
DDT	0.01	81	40	56	36	—	—	97	90
	.005	83	29	42	33	95	12	82	31
	.0033	38	22	—	—	—	—	—	—
	.0025	—	—	—	—	—	—	73	13
TDE	.02	—	—	—	—	—	—	99	67
	.01	51	35	35	38	89	17	97	40
	.005	9	10	32	47	—	—	79	16
Methoxychlor	.01	93	30	61	53	57	7	—	—
	.005	12	14	35	40	—	—	—	—
Fluoro analog of DDT	.01	44	7	—	—	95	4	—	—
Lindane	.01	83	75	—	—	79	53	85	53
	.005	37	29	98	97	—	—	69	33
	.0025	6	17	47	45	—	—	42	11
Benzene hexachloride (12.8% gamma)	.01	86	40	—	—	13	10	—	—
Toxaphene	.02	—	—	—	—	—	—	79	92
	.01	37	57	72	80	57	12	30	49
	.005	23	23	—	—	—	—	19	31
Chlordane	.01	46	60	100	100	59	45	—	—
	.005	24	20	63	61	—	—	—	—
Parathion	.005	—	—	—	—	—	—	96	98
	.0025	43	76	99	100	62	97	87	94
	.002	23	84	70	99	—	—	61	79
Heptachlor	.0033	52	24	—	—	94	28	—	—
Aldrin	.0025	26	75	47	63	85	55	—	—
	.002	13	68	18	65	—	—	—	—
Dieldrin	.0025	43	76	87	96	92	86	—	—
	.002	50	76	—	—	—	—	—	—
Checks	——	4	6	9	15	6	2	4	6

species at 63° or 68° F. than at 93°. For example, with floodwater *Aedes,* DDT at 0.0033 p.p.m. killed 38 per cent of the larvae at 63°, whereas at three times that concentration, 0.01 p.p.m., the kill was only 40 per cent at 93°. Parathion was more toxic to all species at 93° than at 63° or 68°. Aldrin and dieldrin were more toxic to *Aedes* at 93° than at the lower temperatures. Toxaphene and chlordane were about equally effective against all species at the high and the low temperatures. Chlordane was not tested against *C. stigmatosoma.* TDE, methoxychlor, the fluoro analog of DDT, heptachlor, lindane, and benzene hexachloride gave the best kills of floodwater *Aedes* and *Culex* at the low temperatures, but results were variable with *A. nigromaculis.* Temperature did not cause so much variation in the toxicity of the different chemicals against *A. nigromaculis.*

The difference in effectiveness between high and low temperatures may be due

to loss of vigor and resistance when the larvae are not reared at the optimum temperature. With *Culex,* a warm-weather species, the rearing of larvae at low temperatures probably causes a decrease in the insects' vigor. In the case of floodwater *Aedes,* however, it appears that low temperatures are not primarily responsible for low vitality, since in nature this species grows at 55° to 70° F. Rate of metabolism may be a factor in the insect's resistance or lack of resistance to the effects of an insecticide. Insect metabolism decreases with lowering of temperature, and mode of action of the different insecticides probably varies greatly. In the case of DDT, the lower metabolic rate may not result in detoxification by the insect, whereas this process is more complete at high temperatures with consequent low kill of larvae. However, in the case of parathion, aldrin, and other insecticides that are more effective at high temperatures against floodwater *Aedes* than at low temperatures, a different mode of action may give the higher kills.

Some of the larvicides showed a selective action on various species, different concentrations being required to obtain equivalent kills. For example, DDT at 0.005 p.p.m. killed 83 per cent of floodwater *Aedes* at 63° F. and 29 per cent at 93°, and the same concentrations killed only 42 and 33 per cent, respectively, of *A. nigromaculis.* Lindane and chlordane, on the other hand, were more toxic to *A. nigromaculis.* A concentration of 0.005 p.p.m. of lindane killed 98 per cent of *A. nigromaculis* at 68° and 97 per cent at 93°, and the same concentration with floodwater *Aedes* gave only 37 per cent and 29 per cent kills.

Summary—In laboratory tests to determine the effect of temperature on the toxicity of chemicals to mosquitoes DDT was found to be consistently more effective to several species of mosquito larvae at 63° or 68° F. than at 93°, whereas parathion was more toxic to all species at 93°. Toxaphene and chlordane were about equally toxic at the high and the low temperatures. Dieldrin and aldrin were more toxic to *Aedes* at 93° than at 68°. TDE, methoxychlor, the fluorine analog of DDT, heptachlor, lindane, and benzene hexachloride gave the best kills of floodwater *Aedes* and *Culex* at the low temperatures.

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IT WILL BE A GOOD INVESTMENT to attend the Annual Meeting of the American Mosquito Control Association in Chicago on March 5, 6, 7 and 8. You will profit in knowledge gained and contacts made, and your presence will contribute to its success. See page 217 of this issue, and read the announcements which you receive.