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Resistance of Body Lice[1] to Carbaryl[2]

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ABSTRACT

A strain of body lice, *Pediculus humanus humanus* L. developed only 4-fold resistance to carbaryl at the LC_{50} level after being selected with carbaryl for 55 generations. However, by the 71st generation, the resistance jumped to at least 67-fold. The lice also became highly resistant to DDT, but their resistance to lindane decreased. Synergized carbaryl was effective against the carbaryl-resistant strain.

DDT-resistance in the body louse, *Pediculus h. humanus* L., was first noted in 1952 by Hurlbut, Altman, and Nibley in Korea. Shortly thereafter DDT-resistant lice were found in Japan, Egypt, and France. The U. S. Armed Forces, therefore, changed from DDT to lindane (gamma benzene hexachloride) louse powder to control the Korean lice. However, Yasutomi reported the discovery of benzene hexachloride-resistant lice that same year, and in 1955 Nicoli and Sautet found lice resistant to lindane in southern France. In their worldwide survey of insecticide resistance in body lice in 1957 Wright and Brown reported that all samples collected in Japan showed low mortality with lindane, and Smith (1957) discovered a strain of lice with 7-fold resistance to lindane at Freetown, Sierra Leone, Africa (Freetown A colony).

In 1964 Clark and Cole reported the development of a high level of resistance to lindane in lice originating from the Freetown A colony. After they had selected this colony with lindane in the laboratory for 65 generations, it developed 370-fold resistance to lindane at the LC_{50} level and more than 10,000-fold resistance at the LC_{99} level, compared with lice from the Regular colony.

Because lice were becoming resistant to both lindane and DDT, malathion was considered as a replacement. Cole and Burden in 1956 and Cole et al. in 1958 found it effective in the laboratory as a louse powder. Their attempts with 3 colonies—the Regular, Freetown A, and Korean A—to develop a malathion-resistant strain were without success. In 1962 Barnes et al. in Korea and Shawarby et al. in Egypt found malathion effective as a 1% powder in field tests. However, because of its disagreeable odor, there have been some objections to malathion as a louse powder. Also, malathion in dust formulations deteriorated rapidly in storage, especially at very low concentrations.

Carbaryl has recently received considerable attention as a potential louse powder. Cole and Clark reported in February 1962 that carbaryl had a long residual effect against adult lice and was highly synergistic with sulfoxide and piperonyl butoxide. In sleeve tests against DDT-resistant lice, pyrophyllite powders containing 2% carbaryl + 2% sulfoxide were 100% effective for more than 28 days. Powders containing 1% carbaryl + 1% sulfoxide or 5% carbaryl alone were 98–100% effective for only 10 days. An unpublished report by P. J. Geldenhuys, which we have been permitted to cite, states that in May 1962 field trials were made with 2.5% carbaryl powder to determine its effectiveness for typhus control at Glen Grey District, Union of South Africa, by the State Department of Health. The powder was 100% effective against lice except in 1 case, when 5 live lice were found in the seam of a blanket.

To learn whether lice could develop resistance to carbaryl, a strain called the Freetown C colony was started in 1959 at the Orlando laboratory from the Freetown A, F_{11} generation. It was selected with carbaryl for 85 generations. This paper is a report of the development of resistance to carbaryl by this strain of lice.

METHODS. — In each generation, the 10-day-old nymphs were exposed for 24 hr to cloth treated with acetone solutions of carbaryl. The concentration of carbaryl was 0.025% in the 1st 15 generations but was increased to 0.05% from the F_{16} through the F_{70} generations and to 0.1% from the F_{71} through the F_{85} generations, with the exception of the F_{78} generation. The 10-day-old nymphs of the 78th generation were exposed for 24 hr to cloth treated with 10% carbaryl; the result was 85% mortality of the entire colony. Another colony was started from the Freetown C F_{62}

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Table 1.—Resistance to carbaryl of Freetown C body louse colony. (Beaker tests; 3 replications of 20 lice each; LC_{50} and LC_{90} expressed as percent insecticide in acetone solution used to treat cloth.)

Generation	LC_{50} %	LC_{50} Ratio to regular colony	LC_{90} %	LC_{90} Ratio to regular colony
Parent	0.033	0.55	0.087	0.51
14	.099	2.5	.47	2.7
25	.19	4.0	.94	5.1
36	.18	3.2	1.1	5.5
47	.16	1.4	1.7	2.9
51	.14	3.7	>10.0	>14.0
55	.093	4.0	10.0	69.0
71	>10.0	>67.0		
75	>10.0	>156.0		
85	>10.0	>285.0		

generation by exposing adult lice for 24 hr to cloth previously treated with 10% carbaryl in acetone. After 3 generations, this group of lice was discontinued because the concentration resulted in too high a mortality.

The beaker method described by Cole et al. (1960) was used to determine the degree of resistance of the Freetown C colony to carbaryl by comparing it with the Regular colony lice. This method consisted of saturating patches of wool cloth with acetone solutions of carbaryl at 7 concentrations and drying the cloth patches on pins before placing them in 50-ml beakers. Twenty adult lice, 10 ♂ and 10 ♀, were placed on each patch, and the mortality was determined after exposure for 24 hr at a constant temperature of 80°F and 60–70% RH. Three replications were made with each concentration; the LC_{50} and LC_{90} were calculated by the method of Litchfield and Wilcoxon (1949).

RESULTS AND DISCUSSION.—Results are shown in Table 1. When the lice were taken from the Freetown A colony to start the Freetown C colony, they were even more susceptible to carbaryl than the Regular colony lice. After 14 generations of selection with carbaryl, they had developed only 2½-fold resistance. By the 25th generation the resistance had increased to 4-fold at the LC_{50} level and it was still only 4-fold after 55 generations of selection. However, by the 71st generation more than 67-fold resistance had developed; at 10%, the highest concentration used, less than 50% of the lice were killed. Even in other tests with the highest concentration of carbaryl soluble in acetone (20%) only 30% mortality occurred and when the lice were allowed to wallow in the technical powder (99.5% pure) for 24 hr, only 20% were killed. Apparently the Freetown C colony has become practically immune to carbaryl.

Table 2.—Resistance to DDT of Freetown C body louse colony (Beaker tests; 3 replications of 20 lice each; LC_{50} expressed as percent insecticide in acetone solution used to treat cloth.)

Generation	LC_{50} %	LC_{50} Ratio to regular colony
Parent	0.13	22.0
17	.074	7.5
25	.012	1.4
36	.006	.51
51	.015	.76
55	.045	3.3
75	.175	5.3
85	>20.0	>458.0

Table 3.—Resistance to lindane of Freetown C body louse colony. (Beaker tests; 3 replications of 24 lice each; LC_{50} expressed as percent insecticide in acetone solution used to treat cloth.)

Generation	LC_{50} %	LC_{50} Ratio to regular colony
Parent	0.041	69.0
16	.018	36.0
26	.0035	7.0
43	.0026	4.3
85	.00087	1.6

The resistance of the Freetown C colony to DDT was investigated to determine whether a negative correlation existed between the resistance to carbaryl and DDT. The resistance to DDT at the LC_{50} level (Table 2) dropped from 22-fold in the parent generation to 1.4-fold by the 25th generation and to 0 by the 36th generation. In this period, the colony had developed only a 3-fold resistance to carbaryl. However, at the 55th generation the colony started to become resistant again to DDT. When the 78th generation was subjected to 10% carbaryl, it also became highly resistant to DDT, greater than 458-fold at the LC_{50} level, proving conclusively that resistance to carbaryl was not negatively correlated with that to DDT.

The results of tests of the resistance of the Freetown C colony to lindane are presented in Table 3. At the LC_{50} level, this colony had a 69-fold resistance to lindane when it was taken from the parent colony. The resistance dropped to 36-fold at the 16th generation, to 4-fold by the 43rd generation, and to 1.6-fold after 85 generations of selection with carbaryl. Unlike the DDT resistance, the lindane resistance was unaffected by elimination of all but the lice most highly resistant to carbaryl in the 78th generation.

A comparison of the effectiveness of carbaryl with and without the synergist sulfoxide was made against the Freetown C (resistant) and Regular (susceptible) colonies (Table 4). The synergized carbaryl was effective against the resistant colony compared with carbaryl alone: a concentration of 0.5% carbaryl plus 0.1% sulfoxide killed 90% of the lice from the Freetown C colony; 0.5% carbaryl alone killed only 10%. (A concentration of 0.1% sulfoxide did not kill any of the lice.) However, there was not much difference in the effectiveness of carbaryl with sulfoxide and carbaryl alone against the Regular colony, though the synergized carbaryl was more effective against the susceptible lice than against the resistant lice: a concentration of 0.1% carbaryl + 0.02% sulfoxide killed 100% of the Regular colony lice but only 30% of those of the Freetown C colony.

Table 4.—Effectiveness of sulfoxide as a synergist for carbaryl in beaker tests against Freetown C (carbaryl-resistant) and Regular (susceptible) strains of body lice. (Ratio of carbaryl to synergist 5:1. Average of 3 replications of 20 lice each.)

Colony	Insecticide combination	Percent mortality of lice at indicated concentration of carbaryl[a]						
		10	5	1	0.5	0.1	0.05	0.01
Freetown C (F_{85} Gen.)	Carbaryl + sulfoxide	98	95	95	90	30		
	Carbaryl alone	8	10	12	10	0		
	Sulfoxide alone	45	32	2	0	2		
Regular	Carbaryl + sulfoxide			100	100	100	75	13
	Carbaryl alone			100	98	90	73	7
	Sulfoxide alone	52	23	3	2	3		

[a] The concentration of sulfoxide was always ½ that indicated for carbaryl.

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Persistence of Low-Volume and Standard Formulations of Malathion on Lima Bean Foliage[1]

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ABSTRACT

Chemical analyses and bioassays showed that applications of low-volume (LV) undiluted technical malathion applied in the laboratory to lima bean foliage with apparatus that insured uniform distribution produced a higher initial residue than formulations of malathion in an oil solution or in water emulsion, probably because degradation took place at different rates. An initial residue of LV malathion of 6.25 $\mu g/cm^2$ declined to 1.2 $\mu g/cm^2$ in 8 days and dropped below detectable limits in 12 days. Initial residues of 5.2 or 4.5 $\mu g/cm^2$ of malathion from the water and oil formulations declined to 2.9 and 2.1 $\mu g/cm^2$, respectively, in 2 days and dropped below detectable limits in 4 days. When adult Mexican bean beetles, *Epilachna varivestis* Mulsant, were fed leaves treated with the 3 formulations, the bioassays correlated well with chemical analyses. No mortality occurred on 9-day-old residues from the water or oil formulations, but 70% mortality occurred on 22-day-old residues from LV applications. Washing removed residues completely from leaves treated with the water emulsion, removed an intermediate amount from leaves treated with the oil formulation, and removed the least when LV applications were made.

Residues of malathion vary in initial deposit and rate of decline after application when the insecticide is applied in aerosols, dusts, wettable powders, or emulsion sprays to vegetable crops in the field or greenhouse (Smith et al. 1954, 1955; Wallis et al. 1957). The amount of residue on vegetables can be reduced by washing in water or in commercial processing plants (Smith et al. 1955). However, recent reports of increased kill of insects when sprays of low volume (LV) technical (undiluted) malathion are applied from airplanes (Messenger 1964, Skoog et al. 1965) suggested the need for information on initial

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