being resistant to *m*-isopropylphenyl N-methylcarbamate and Isolan exhibit following level of cross resistance to each compound; namely, high levels of cross resistance to substituted alkyl-and alkoxyphenyl N-methyl and N, N-dimethylcarbamates, biochemically limited cross resistance to certain heterocyclic carbamates, high levels of cross resistance to hydrochlorinated insecticides, limited cross tolerance or cross rsistance to organic phosphate insecticides peculiar to each compound, and cross tolerance to allethrin.

Cross resistance spectrum of Sevin-resistant house fly are significantly different to that of the house fly strains resistant to *m*-isopropylphenyl N-methylcarbamate and Isolan.

From the result mentioned above, it may be concluded at this point that carbamate insecticides are divided into two groups and/or more.

Joint Toxic Action of Mixtures between Lindane and Hercules 5727 against the Common House Fly. Studies on the Biological Assay of Insecticides. XLIII. Sumio Nagasawa and Michiyo Shiba (Ihara Agricultural Chemicals Institute, Shimizu). Received Oct. 31, 1964. *Botyu-Kagaku*, 29, 73, 1964.

15. Lindane と Hercules 5727 のイエバエにたいする連合作用毒性 殺虫剤の生物試験に関する研究 第43報

長沢純夫・柴三千代（イハラ農薬研究所）39. 10. 31 受理

Lindane と Hercules 5727 のイエバエの成虫に対する連合作用毒性は致死に関して相乗効果をしめした．なお両薬物の混合比は 3.7 : 2.3 としたときに最大の致死効果がえられるものと推定された．

There are two basic purposes for which insecticides could be used in mixtures. First, they might be mixed to reduce labour by increasing the number of insect pest species or the number of developmental stages controlled by a single application, and second, to obtain an improved level of control utilizing the synergistic joint toxic action arising between insecticides. Although synergism is not common in insecticide combinations, the writers wish to report a simple synergistic type of toxic action found between lindane and Hercules 5727 against the common house fly.

Materials and Methods

Insect: The so-called "Takatsuki" strain of the common house fly, *Musca domestica vicina* Macquardt, was used in these experiments. The larvae were reared on the culture media prepared with the residual product of "tofu" making and the adults were given sugar and water as their diet.

Insecticides: The sample of lindane used was of technical grade containing> 99% of gamma isomer. The research grade sample of Hercules 5727 (N-methyl *m*-isopropylphenyl carbamate, sample number XA 24-122-2) used was obtained from the Agricultural Chemicals Laboratory of Hercules Powder Co. in February, 1962. Mixing ratioes between these chemicals adopted for the present experiments were 6:0, 5:1, 4:2, 3:3, 2:4, 1:5, and 0:6. The highest concentration 1 $\mu g/mm^3$ of solutions of these insecticides and mixtures were prepared with acetone and then diluted with acetone to form logarithmically spaced series in which each concentration was multiplied by 2 to obtaine the next lower concentration.

Method of testing: Flies were lightly anaesthetized with carbon dioxide and sexed. Female adults, in groups of about 40 individuals, were kept separately in glass vials, 9cm in diameter and 7cm high, with diluted milk. Just prior to the application of insecticides, the flies were slightly anaesthetized again with carbon dioxide. One mm^3 of acetone solution of lindane or Hercules 5727, or mixtures of these two insecticides, was applied topically to the notum of the house fly using a micrometer driven syringe. Acetone alone was applied as the control. After treatment the flies were returned to the same vial with diluted milk. Mortality determinations were made at 24 hours after treatment. Rearing and testing were carried out in a room maintained at 25°C and 70% relative humidity. The duration of this experiment was from Dec. 5 to 26, 1963.

Results and Discussion

The results of the experiment, presented as the relation between dosage X (μg/fly) and mortality Y(%) for each insecticide and for the mixtures of these two insecticides, are shown in Table 1. The mortalities shown in Table 1 were corrected by Abbott's formula for the mortality in the control(7.5%). In order to avoid negative quantities, all dosages were multiplied by 100 before logarithms were taken. Then dosage X and mortality Y were transformed to logarithms x and probits y respectively; and their relations were plotted in a graph. The calculation of the dosage-mortality regression lines and χ^2-test for the agreement between experimental data and the calculated result were made by the standard method of probit analysis (Bliss[1]). Then the test of parallelism of the regression lines was made by comparing the sums of the values for the seven series with that obtained by a similar process from the total sums of squares and products (Finney[2]). As shown in the result of Table 2, there is no evidence of any conflict with the hypothesis that the seven regression lines are parallel and it has been considered to be satisfactorily fitted by the seven parallel regression lines shown as equations in the second column of Table 3. From these equations, log LD_{50} (+2.000) and LD_{50} (μg/fly) were calculated and shown in the third and the fourth columns respectively. The relation between log LD_{50} and the relative quantity of both insecticides was shown in Fig. 1. In this figure, the dotted line is from the equation

Table 1. Dosage (μg/♀)-per cent mortality of adults of the common house fly, *Musca domestica vicina* Macq., for lindane, Hercules 5727, and their mixtures applied topically in acetone.

Mixing ratio of lindane and Hercules 5727		Dosage 0.03125	0.0625	0.125	0.25	0.5	1.0
6 : 0	No. of flies used	121	240	240	238	236	240
	Mortality	11.6	27.5	44.7	80.0	91.2	97.7
5 : 1	No. of flies used	122	122	118	121	120	121
	Mortality	25.5	21.0	62.5	81.2	96.4	100
4 : 2	No. of flies used	162	160	168	162	159	120
	Mortality	14.6	48.7	67.1	90.7	99.32	100
3 : 3	No. of flies used	120	245	241	239	237	240
	Mortality	0.0	32.5	68.7	90.1	98.63	100
2 : 4	No. of flies used	160	162	158	161	162	161
	Mortality	9.5	41.3	48.0	86.0	98.67	100
1 : 5	No. of flies used	121	120	119	101	119	117
	Mortality	2.6	20.8	31.9	77.5	90.1	100
0 : 6	No. of flies used	—	240	253	248	237	244
	Mortality	—	5.8	21.8	38.1	82.5	91.1

Table 2. Analysis of χ^2 for parallelism of regressions.

Source of variation	Degrees of freedom	Sum of squares	Mean square
Parallelism of regression	6	37.65352	6.27558
Residual heterogeneity	21	97.77839	4.65611
Total	27	135.43191	—

Table 3. Dosage-mortality regression equations reculculated with combined slope and median lethal dosages.

Mixing ratio between lindane and Hercules 5727	Regression equation $Y=a+bX$	log LD_{50} (+2.00000)	LD_{50} μg/fly	Measure of synergism Δ_s
6 : 0	$Y=2.25245+2.50940X$	1.09490	0.1244	—
5 : 1	$Y=2.48856+2.50940X$	1.00081	0.1019	0.339 ± 0.070
4 : 2	$Y=2.82117+2.50940X$	0.86827	0.0738	0.785 ± 0.066
3 : 3	$Y=2.62158+2.50940X$	0.94780	0.0886	0.712 ± 0.060
2 : 4	$Y=2.53644+2.50940X$	0.98173	0.0959	0.770 ± 0.067
1 : 5	$Y=2.05022+2.50940X$	1.17549	0.1498	0.449 ± 0.083
0 : 6	$Y=1.40694+2.50940X$	1.43184	0.2703	—

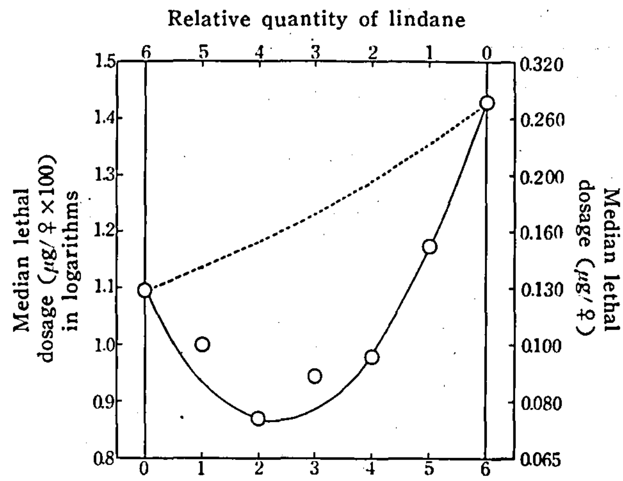

Fig. 1. Exploring chart of joint toxic action between lindane and Hercules 5727 for adults of the common house fly, *Musca domestica vicina* Macq.

$Y=2.25245-2.50940\log(\pi_1-\rho_2\pi_2)-2.50940x$ which is predicted theoretically for the 50% level of mortality when lindane and Hercules 5727 joint act similarly (Finney[2]). In this equation, π_1 and π_2 are the proportions of the two insecticides and ρ_2 is the relative toxicity of two insecticides. The toxicity of the second insecticide relative to that of the first is given by

$$\log\rho_2=(a_2-a_1)/b$$

and the result of calculation is $\rho_2=0.46033$. If the experimental curve of 50% level of mortality is above the dotted line mentioned previously, we can consider that the joint toxic action between two insecticides acted antagonistically, and if it is below the dotted line, it can be concluded that the joint toxic action between them acted synergistically. As is seen in Fig. 1, the joint toxic action between lindane and Hercules 5727 is considered to be a synergistic type. As shown in the first colum of Table 3, the measure of synergism calculated by the equation $\Delta_s=a_3-a_1-b\log(\pi_1-\rho_2\pi_2)$ are all positive (Finney[2]), and the values which are significantly different from zero and which therefore show that the indication of synergism is far from the limits of sampling variation.

Here it might be possible to fit a parabolic equation, $Y=az^2+bz+c$, $c\neq0$, for the relation between log LD_{50} of Table 3 and relative quantity of Hercules 5727 to lindane z. The result of calculation is

$$Y=0.04196z^2-0.19277z-1.08259.$$

The computed line has been plotted with solid line in Fig. 1. Since $c>0$ in this equation, if the minimum of $z=-\frac{b}{2a}$ is calculated to get the minimum of $Y=-\frac{b^2-4ac}{4a}=0.86118$, the relative quantity of Hercules 5727 to lindane in which the maximum synergistic action is obtained could be determined theoretically. The minimum of z calculated is 2.297. It is concluded that the maximum synergistic toxicity for the house fly would be obtained when lindane and Hercules 5727 were mixed in the ratio of 3.7:2.3.

Summary

Joint toxic action between lindane and Hercules 5727 for the common house fly was synergistic. The maximum mortality would be obtained when lindane and Hercules 5727 were mixed in the ratio of 3.7:2.3.

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Genetic Analyses of DDT-Resistance in Two Strains of The Housefly, *Musca domestica* L.*

Masuhisa Tsukamoto and Reiko Suzuki (Department of Genetics, Osaka University Medical School, Osaka, Japan) Received Nov. 5, 1964. *Botyu-Kagaku* **29**, 76, 1964.

16. イエバエにおける DDT 抵抗性の遺伝学的分析

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従来イエバエの殺虫剤抵抗性の遺伝に関する論文は数多く報告されているが，そのほとんどは簡単な交配実験の域を出ないものであって，その結論についても遺伝学的には不適切不充分なものが多かった．そこで筆者らはイエバエのいくつかの可視突然変異を用いて起原の異なる DDT 抵抗性の２系統の DDT 抵抗性および DDT＋DMC 抵抗性について遺伝学的分析をおこなった．その結果，イエバエの DDT 抵抗性には，すくなくとも第２染色体の不完全劣性遺伝子および第５染色体の優性遺伝子の２つの主要遺伝子が含まれていること，そのうち第５染色体の抵抗性遺伝子は *cm* ミュータントの近くに存在していることなどが明らかとなった．また，この第５染色体の DDT 抵抗性遺伝子は DDT の協力剤 DMC によってその働きが抑制されるが，第２染色体の遺伝子ではそのような影響は認められなかった．DMC は DDT 脱塩酸酵素の阻害剤でもあるので，第５染色体の抵抗性遺伝子は脱塩酸酵素による DDT の代謝を支配していること，第２染色体の抵抗性遺伝子は DMC では阻害されない別の抵抗性メカニズムに関与していることなどが推論された．

Inheritance of knockdown-resistance to DDT in an Italian strain of the housefly was first found by Harrison[7] in 1951 to be due to a single recessive genepair. Since then, a number of studies on the inheritance of resistance to insecticides, such as crossing experiments between genetically unmarked strains, were reported in various insects. These results on the mode of inheritance were reviewed by Brown[2], Crow[4], Davidson and Mason[6], Milani[19,21], etc. Especially on DDT-resistance of the housefly, some investigators indicated that a simple recessive factor was concerned to the knockdown-resistance (Barbesgaard and Keiding[1], Keiding[11], and Milani[18]) or that a dominant monofactorial one was concerned to the inheritance of kill-resistance (Lichtwardt[13] and Maelzer and Kirk[16]). However, the majority of early investigators concluded that multifactorial systems were responsible for the kill-resistance to DDT because they could not find any evidence of a typical Mendelian segregation in filial generations of crosses between resistant and susceptible strains (Bruce and Decker[3], D'Alessandro and Mariani[5], La Face[12], March[17], Norton[24], etc.). Maelzer and Kirk[16] also reported that, although the inheritance of high DDT-resistance was monofactorial, the inheritance of intermediate (or "weak") resistance to DDT seemed to be multifactorial. In addition,

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