

Inheritance of DDT-Resistance in Body-Lice

A Preliminary Investigation

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The interpretation of surveys of DDT-resistance in body-lice is handicapped by the fact that the genetics of this form of resistance have not been studied. This paper reports on a preliminary investigation on normal and resistant strains of lice, F_1 and F_2 hybrids of a mass cross and $F_1 \times R$ hybrids exposed to DDT dust and DDT-impregnated paper of various concentrations. The results were consistent with inheritance by a single gene pair (or possibly a small number of genes). The F_1 hybrids were intermediate in tolerance but were all killed by 5% DDT dust. This confirms a suggestion that 5% DDT dust would be suitable for testing for incipient resistance.

Wright & Pal (1965) gave the results of a second survey of insecticide-resistance in body-lice, in which they collated the results of tests on lice collected in the field in 22 countries. The test method was that of Wright & Brown (1957), in which batches of lice are exposed to insecticidal dust spread over cloth. It does not give a good correlation between dosage and mortality, when used in the field; and furthermore the mortality observed with the lowest concentration is often too high to allow calculation of an LC_{50} value. Accordingly, Wright & Pal (1965) included lower concentrations of insecticidal dusts. This did not greatly improve matters in the field tests; but the Orlando laboratory strains gave good regression lines, with kills at the lower concentrations sufficiently low to allow estimation of LC_{50} values. The authors suggest that this could be due to low-level resistance ("vigour tolerance"), a possibility which will be discussed in the next section. They point out that no one seems to have investigated the genetics of DDT-resistance in lice, which handicaps interpretation of the results.

This paper describes a preliminary investigation of the subject. Unfortunately it was limited in time, since the author was obliged to go abroad and terminate the work about 4½ months after commencing it. It seems, however, worth recording the investigation so far as it went.

TECHNIQUES

The louse colonies were maintained in mesh-covered tins, worn daily on the ankle as described

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by Buxton (1947). Since all the lice were fed in this way by myself and an assistant, the numbers available for experiments were somewhat restricted.

Two methods of assessing resistance levels were employed: (1) by exposure to DDT dusts, as described by Wright & Pal (1965); and (2) by exposure to DDT-impregnated papers, as described by Busvine & Lien (1961). In both cases an exposure of 24 h in darkness at 27°C was used.

EVALUATION OF THE LOUSE STRAINS

Both strains were very kindly supplied by the Entomology Research Service, US Department of Agriculture, through the courtesy of Mr M. M. Cole.

The susceptible colony

The strain supplied was the Orlando Regular colony, a subcolony of which had been sent earlier, in 1961, for work on genetics of dieldrin-resistance (Guneidy & Busvine, 1964). Owing to warnings of possible incipient resistance in this strain, reverse selection was employed for 2 generations, as follows. Of the large numbers of lice which survived the journey, about 60 nymphs were fed and exposed to WHO papers impregnated with 4% or 2% DDT (as used in the WHO test method for mosquitos). The exposures were made at 17°C to accentuate the effects of DDT, and after 4 h those showing signs of intoxication were removed and put into feeding boxes worn on the leg. Most of them recovered, eventually matured and laid eggs. The same process was followed with their progeny, so that in 2 genera-

tions lice not showing early signs of DDT poisoning at low temperature were discarded. (This method of reverse selection was first used, with houseflies, by Keiding (1957).)

Resistance tests, by exposure to DDT-impregnated papers, were conducted with some of the original lice (which arrived in March 1966). Fed adults only were used. The results are given below, in comparison with tests on other colonies, believed to be DDT-susceptible, and with the same colony after 2 generations of reverse selection.

Strain	Tested	% kill by DDT paper:			
		4% DDT	2% DDT	1% DDT	0.5% DDT
Cairo	1960	—	68	38	—
Orlando	1961	89	50	—	—
Orlando	1966	94	65	37	—
Reverse selected					
Orlando	1966	97	69	51	0

The dust test method was used only after reverse selection of the colony and gave results which may be compared with colonies (1) and (11) mentioned by Wright & Pal (1965).

	% kill by DDT dust:			
	5% DDT	1% DDT	0.2% DDT	0.04% DDT
Orlando colony (1)	98	75	27	2
Orlando colony (11)	100	82	51	18
Reverse selected				
Orlando colony	100	91	63	28

There is a slight increase in sensitivity, as compared with colony (11), but the over-all average kill was only 79%. Wright & Pal (1965) pointed out that the average kill in field tests is 92%, but it is possible that this higher figure may be due to different environmental conditions (probably lower temperature and partial starvation in field tests, which could increase sensitivity to DDT), rather than to partial resistance of the laboratory colonies.

The average mortality from a range of concentrations is not a very satisfactory logical criterion and it may be noted that in many cases quoted by Wright & Pal (1965) it is inflated by high values at 0.04% DDT (sometimes above those given by 0.2% DDT). This is strange in view of the results of Bushland et al. (1945), who never obtained complete mortality with 0.05% DDT at a time when DDT-resistance was presumably very rare.

On the basis of this evidence, then, it will be assumed that in the susceptible colony used (designated "N" below) resistance genes were substantially, if not completely, absent.

Resistant colony

The resistant colony (R), supplied in May 1966, was of the Korean strain. Tested by the paper method, it gave zero mortality at the highest level. The powder method, however, gave a partial mortality (44%) on 5% DDT which was higher than would be expected from Wright & Pal's results.

TABLE 1
OBSERVED AND EXPECTED MORTALITIES OF NORMAL AND RESISTANT STRAINS OF LICE,
AND CROSSES BETWEEN THEM, EXPOSED TO DDT DUST^a

DDT dust (%)	Mortality (%)								
	R	N	F ₁	F ₂			F ₁ × R		
				Obs.	Expected		Obs.	Expected	
					1 gene	2 genes		1 gene	2 genes
5	44 (38)	100 (19)	100 (15)	81 (16)	86	88	84 (19)	72	67
1	8 (10)	91 (44)	72 (24)	55 (15)	61	64	49 (21)	40	41
0.2	—	63 (44)	0 (12)	0 (10)	15	12	—	—	—
0.04	—	28 (23)	0 (13)	—	—	—	—	—	—

^a The mortality figures are the averages for males and females. The numbers of lice tested are shown in parentheses.

TABLE 2
OBSERVED AND EXPECTED MORTALITIES OF NORMAL AND RESISTANT STRAINS OF LICE,
AND CROSSES BETWEEN THEM, EXPOSED TO DDT-IMPREGNATED PAPER ^a

DDT paper (%)	Mortality (%)								
	R	N	F ₁	F ₂			F ₁ × R		
				Obs.	Expected		Obs.	Expected	
					1 gene	2 genes		1 gene	2 genes
Observed		Expected		Expected					
4	0 (57)	97 (39)	75 (21)	51 (32)	62	65	42 (26)	48	38
2	—	69 (34)	39 (28)	26 (40)	36	38	20 (30)	34	20
1	—	51 (35)	11 (18)	5 (35)	17	16	—	—	—
0.5	—	0	—	—	—	—	—	—	—

^a The mortality figures are the averages for males and females. The numbers of lice tested are shown in parentheses.

GENETICAL EXPERIMENTS

In the time available (mid-May to the end of July) it was only possible to make the following (mass) crossing experiments:

Cross: R × N (tests on F₁ and F₂)
Outcross: F₁ × R (tests on progeny)

The average mortalities of males and females of various strains and crosses are given in Tables 1 and 2. It will be seen that the values for the F₂ generation are lower than expected on the basis of single-gene inheritance, in both sets of data. Those for the outcross are higher than expected in the dust tests, and lower in the paper tests.

Expectations on the basis of 2 genes for resistance, each contributing equally, were also calculated (making certain assumptions) and are shown in the tables. These values do not agree better than those based on a single gene and in any case the data are too meagre to support an accurate distinction. It can merely be said that the data are not inconsistent with inheritance based on a single gene pair or a small number of genes.

CONCLUSIONS AND PRACTICAL IMPLICATIONS

From this exploratory investigation, it can be concluded that the hybrids between susceptible lice and those resistant to DDT are intermediate in tolerance. In other words, resistance is not clearly dominant or recessive. The high mortality of F₁

hybrids caused by 5% DDT dust suggests that survival at this level, in field tests, is a good indication of true resistance. As Wright & Pal (1965) suggest, this would be a good discriminating dosage, logically preferable to a change in average kill over a range of concentrations. It seems not unreasonable to suggest that the results obtained at the 5% dust level alone gives a fair impression of the over-all results of the survey carried out by Wright & Pal (1965); some results with 5% DDT dust reported by them were:

Country/Area	No. of tests showing survival with 5% DDT			
	0 surv.	1%-5% surv.	6%-20% surv.	>20% surv.
Afghanistan	0	0	4	8
Hong Kong	0	1	0	0
India	6	3	1	0
Pakistan	9	0	0	0
Egypt	0	0	1	15
Jordan	0	1	0	0
Libya	0	0	0	1
Syria	0	0	0	1
Gaza (UNRWA)	0	1	0	4
France	1	1	0	1
Yugoslavia	7	0	0	0

The levels chosen are, indeed, arbitrary; but they could be interpreted as follows.

0 survival: provisionally satisfactory;
1%-5% survival: incipient resistance;
5%-20% survival: established resistance;
> 20% survival: very extensive resistance likely to impede control measures.

RÉSUMÉ

On ne dispose d'aucune donnée concernant le mécanisme génétique de la transmission de la résistance au DDT chez le pou du corps. La présente étude fournit quelques premières indications à ce sujet.

La sensibilité à l'insecticide a été recherchée chez deux populations de poux: une souche à sensibilité vérifiée et affermie par sélection à rebours pendant deux générations, et une souche coréenne particulièrement résistante. Deux méthodes d'épreuve, la méthode normalisée de l'OMS (carré d'étoffe traité par poudre insecticide), et une méthode personnelle (papier-filtre imprégné de DDT) ont été utilisées.

Les épreuves de sensibilité, appliquées aux individus résistants et sensibles, aux hybrides F_1 et F_2 issus du croisement entre ces deux souches, ainsi qu'au produit du croisement entre hybrides F_1 et souche résistante, ont montré, chez les hybrides F_1 , un degré de résistance intermédiaire. La résistance au DDT n'a donc pas un caractère nettement dominant ou récessif; elle se transmettrait par l'intermédiaire d'une seule paire de gènes ou, peut-être, d'un petit nombre de gènes. On a observé une très forte mortalité chez les hybrides F_1 par l'emploi de la poudre de DDT à 5%; il semble que l'étude de la mortalité à cette concentration puisse être retenue comme critère d'un début de résistance à l'insecticide.

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