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by
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DEPARTMENT OF ENTOMOLOGY

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RESISTANCE TO INSECTICIDES IN SOME AUSTRALIAN POPULATIONS OF *BLATTELLA GERMANICA* (L.)

ABSTRACT: The susceptibility of two laboratory and three field strains of *B. germanica* to organochlorine and organophosphorus insecticides was investigated by means of topical application and continuous exposure toxicological methods. High levels of resistance to dieldrin and lower levels of resistance to lindane were found in the field strains. There was no evidence of resistance to organophosphorus insecticides. Compared with a susceptible strain, the organochlorine resistant strains showed significantly enhanced susceptibility to malathion.

INTRODUCTION

In 1953 Heal *et al.* reported the occurrence of chlordane-resistance in a population of the German cockroach, *Blattella germanica* (L.). Since that time resistance to other cyclodiene insecticides and lindane, to DDT and to a few of the organophosphorus (OP) insecticides has been found (Brown, 1966). Apart from this increase in the number of types of resistance, there has been in recent years an increase in the number of populations exhibiting resistance to one or more of the commonly used insecticides (Brown, 1961a; 1963; 1966). A recent review of the status of resistance in *B. germanica* (Brown, 1966) reveals however that most, if not all, of these instances of resistance are known from the Northern Hemisphere. In Australia only one suspected case of cyclodiene-resistance has been recorded (Kerr, 1964).

Since it was first recorded in Australia in 1892 (Froggatt, 1906) *B. germanica* has become a major household problem and has been exposed to insecticidal control for many years. This paper reports the results of a toxicological study conducted on local strains of *B. germanica* and so starts to fill in the gap in the resistance picture of this insect in the Southern Hemisphere.

Material and Methods

The five strains investigated were named according to their place of origin and the history of each prior to colonization in this laboratory (February-May, 1965) is given below.

Armidale—a sub-colony of that maintained in the Department of Zoology, University of New England, Armidale. The colony was established from wild material in 1951 and has not been exposed to insecticides.

Canberra—a sub-colony of that maintained in the Division of Entomology, C.S.I.R.O., Canberra which has been bred for many years without exposure to insecticides.

St. Lucia—established from specimens caught in a dwelling in Brisbane where the history of control was unknown.

Herston—established from specimens caught in a building of the University of Queensland where control measures comprising chlordane, dieldrin and lindane had been used for some years with decreasing effect.

Wharf—established from specimens caught in a deck consignment of timber aboard a ship which, before berthing at Brisbane, had called at a number of south-east Asian ports after sailing from Hong Kong.

The cockroaches were reared in two pound glass jars capped with muslin; the necks of the jars were coated with either Fluon GP1 (Imperial Chemical Industries, England) or a 1 : 1 mixture of petroleum jelly and paraffin oil. Each jar was provided with a cone of filter paper for shelter, water and food in the form of dog biscuits. Newly emerged adults were held in mating jars until oothecae-bearing females were observed. These were then transferred to breeding jars and when oothecae had been dropped, the females were returned to the mating jars. All breeding took place in a controlled environment of 24 $\pm$ 1.5°C, 60 $\pm$ 5 per cent. relative humidity and a 12 hour light : 12 hour dark regime.

The insecticide susceptibility of 14-19 day old adults was determined by two methods. Dosage-mortality data were obtained by applying 1 μl drops of insecticide dissolved in methyl ethyl ketone to abdominal sternites 1-3 of carbon dioxide anaesthetized adults by means of an automatic microapplicator. Fifty males and fifty females in lots of ten were tested at each dosage level. After treatment the insects were placed in 4 oz waxed cups covered with muslin and held at 24 $\pm$ 1.5°C and 60 $\pm$ 5 per cent. relative humidity. In all tests water-soaked cotton wool pads were placed on the muslin tops and if mortalities were recorded for periods in excess of 4 days, food was also added immediately after treatment. Under these conditions control mortalities were low, and never in excess of 5 per cent.

Since Ishii & Sherman (1965) reported that the post-treatment holding period required to achieve maximum significant mortality varied with different insecticides and in different strains of cockroaches, experiments were carried out to evaluate this parameter under our conditions. Maximum mortality was achieved at 14 days for dieldrin, 4 days for lindane and 4 days for malathion, and hence in all subsequent tests mortalities were recorded at these post-treatment intervals. No differences in these intervals were found either between strains or between sexes.

The second toxicological procedure involved continuous exposure to insecticide films and was based on the WHO test for detection of resistance in cockroaches (World Health Organization, 1963). Fourteen hours prior to the test 2.5 ml of an acetone solution of the insecticide were pipetted into a one pint glass bottle which was then rotated until the solvent evaporated. The strengths of the insecticide solutions used were adjusted to give deposits of 10.8 $\mu g/cm^2$ (equivalent to 10 mg/ft^2) for malathion, diazinon and fenthion and 5.4 $\mu g/cm^2$ for dieldrin and lindane. After addition of the cockroaches, ten per bottle with ten replicates, mortality was recorded at appropriate intervals until complete mortality was achieved. If the tests continued for longer than 2 days, a cube of potato was added to each bottle.

In all tests the cockroaches were considered dead if they were on their backs and were incapable of assuming their normal posture; tests showed that such cockroaches invariably died.

After correction for control mortality the data were plotted on logarithmic probability paper and submitted to probit analysis, by a computer, according to the method of Finney (1952). As Finney observed, "the χ^2 test for the heterogeneity of the discrepancies between observed and expected numbers is only valid when the expected numbers are not 'small' ". The computer programme used the size of the expected numbers (either P or Q) as a criterion for the inclusion or exclusion of results for extreme dosages (or exposure times). This criterion therefore reduced the degrees of freedom for χ^2 and in those experiments where all but one or two dosages (or exposure times) were excluded no valid test is available from the programme. The experiments so affected are marked with an * in Tables 1 and 5. Statistical tests for the significance of differences between two LD_{50}, LT_{50} or b values were carried out by the method given by Swaroop (1957).

Results

The log dosage-probit mortality data are shown graphed in Figures 1 and 2 (dieldrin), 3 and 4 (lindane) and 5 and 6 (malathion). Probit analyses of these data yielded the equations for the log dosage-probit mortality regression (1d-p) lines and values of χ^2 shown in Table 1 and the LD_{50} values (μg insecticide per insect) shown in Table 2. Significant departures from straight line relationships occurred in the St. Lucia strain with dieldrin and in the St. Lucia, Herston and Wharf strains with lindane. Inspection of the dosage mortality data (Figs. 1-4) indicates that these departures were due to plateaux in the lower mortality range.

In addition to differences in the weight of male and female cockroaches, the weight of individuals varied between strains (Table 3). To allow more accurate inter-sex and inter-strain comparisons, Table 2 also presents the LD_{50} values in terms of μg insecticide per gram of tissue.

The Armidale strain was accepted as susceptible to organochlorine insecticides because (a) this strain had the significantly lowest LD_{50} values for dieldrin and lindane (Table 2); (b) the 1d-p lines for both sexes had the highest values of b; i.e. slope of the ld-p line (Table 1); and (c) it was a laboratory strain which had not been exposed to insecticides. Hence resistance ratios at the 50 per cent. response level were calculated for the other strains by comparison with Armidale (Table 4). These ratios were calculated both on a μg/insect basis and on a μg/gram basis since both have a use; the former describes the level of resistance of the intact organism and is useful in evaluating field resistance while the latter describes the resistance as a function of the unique tissue of a certain population and has important physiological implications.

Resistance to dieldrin and lindane i.e. cyclodiene resistance, was high in the St. Lucia, Herston and Wharf strains reaching levels of 230X for dieldrin and 86X for lindane on a μg/cockroach basis. While the level of resistance of females was higher than that of males of any strain with respect to dieldrin, the reverse was true with lindane.

The use of Armidale as the reference strain for the calculation of resistance ratios, because of its susceptibility to dieldrin and lindane, led to resistance ratios of less than one for the other strains with respect to malathion. As discussed earlier, because of the nature of the probit analysis programme used, it was not possible to compare statistically the malathion LD_{50} values of the Armidale strain with those of the other strains. However in Canberra, the other laboratory strain, male cockroaches were significantly ($P = 0.05$) less susceptible than Herston males and Canberra females were significantly less susceptible than St. Lucia, Herston and Wharf females. Armidale males and females had higher LD_{50} values than the corresponding sexes in the Canberra strain. Similarly the value of "b" for the Armidale 1d-p lines was greater than that of other strains.

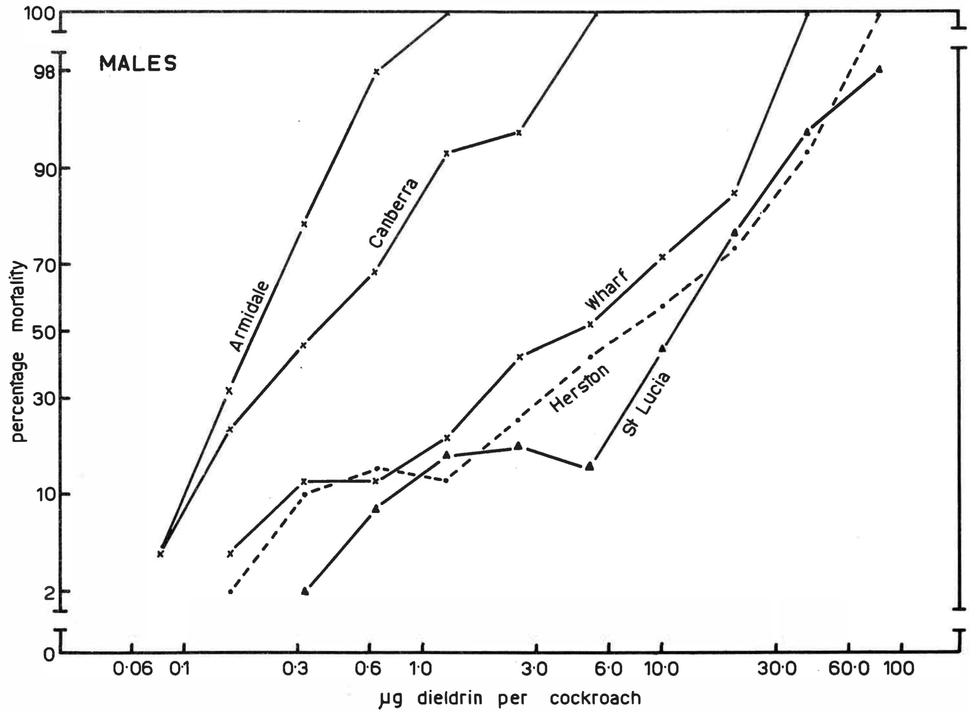

FIG. 1.—Dosage-mortality lines for males of different strains of *B. germanica* obtained with topically applied dieldrin.

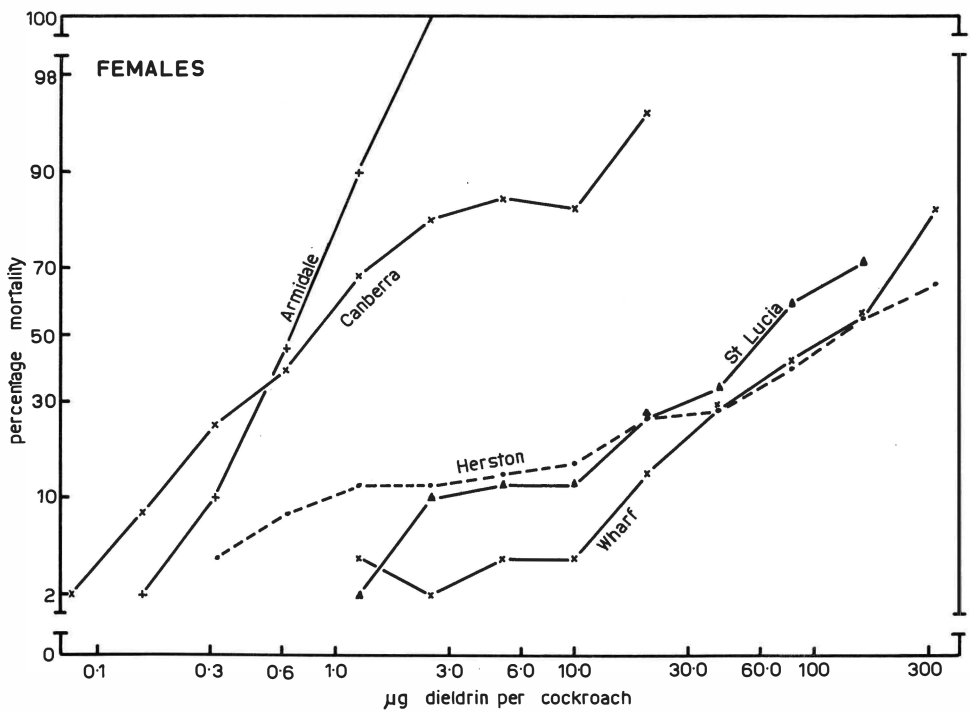

FIG. 2.—Dosage-mortality lines for females of different strains of *B. germanica* obtained with topically applied dieldrin.

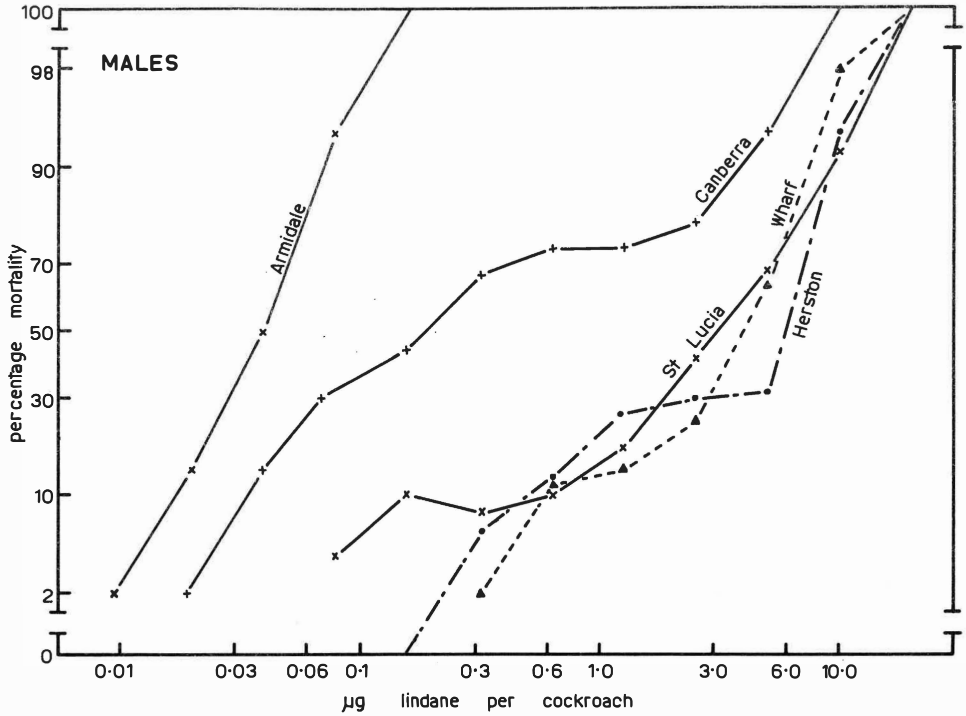

FIG. 3.—Dosage-mortality lines for males of different strains of *B. germanica* obtained with topically applied lindane.

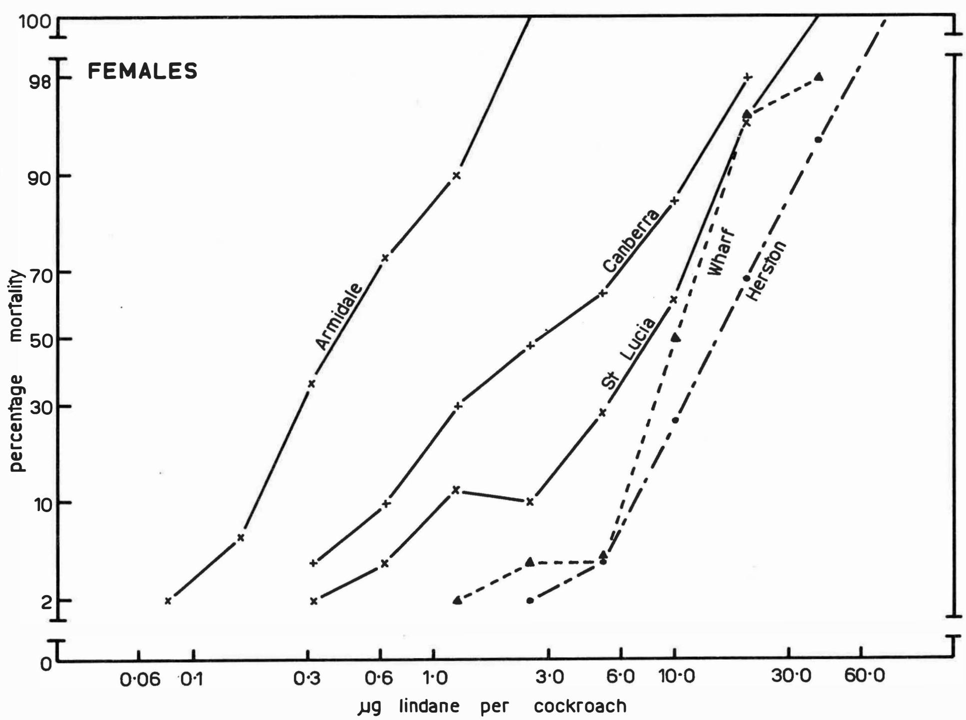

FIG. 4.—Dosage-mortality lines for females of different strains of *B. germanica* obtained with topically applied lindane.

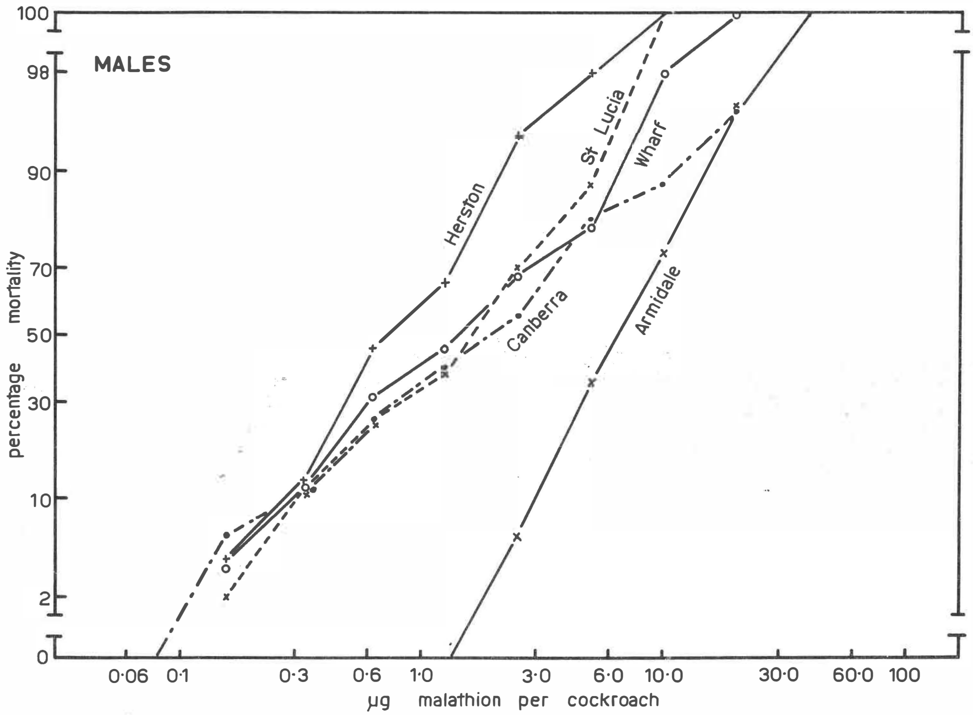

FIG. 5.—Dosage-mortality lines for males of different strains of *B. germanica* obtained with topically applied malathion.

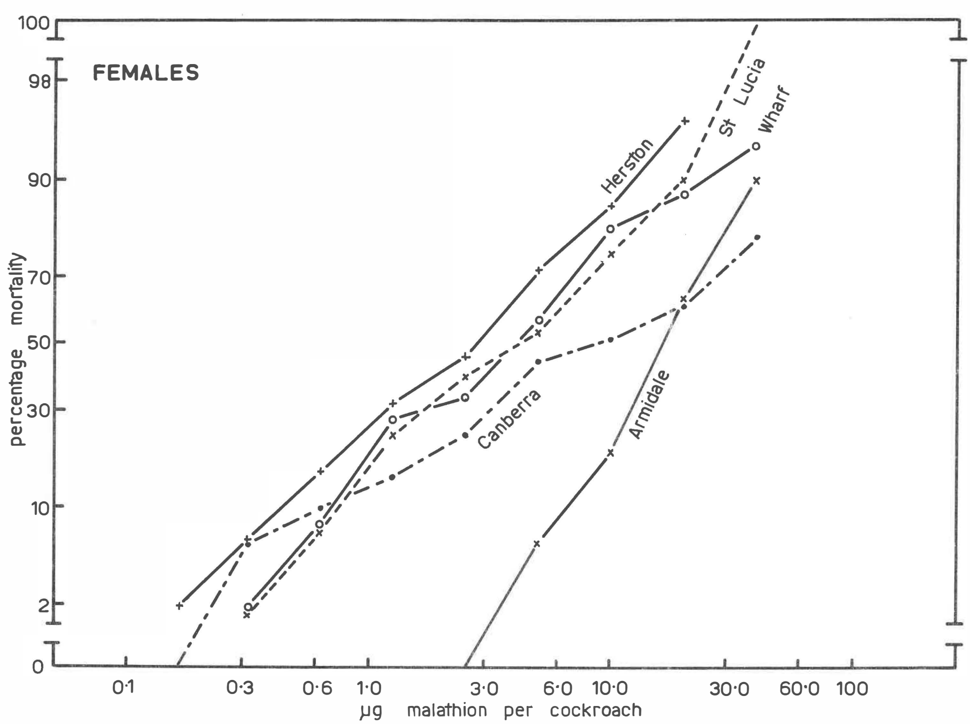

FIG. 6.—Dosage-mortality lines for females of different strains of *B. germanica* obtained with topically applied malthion.

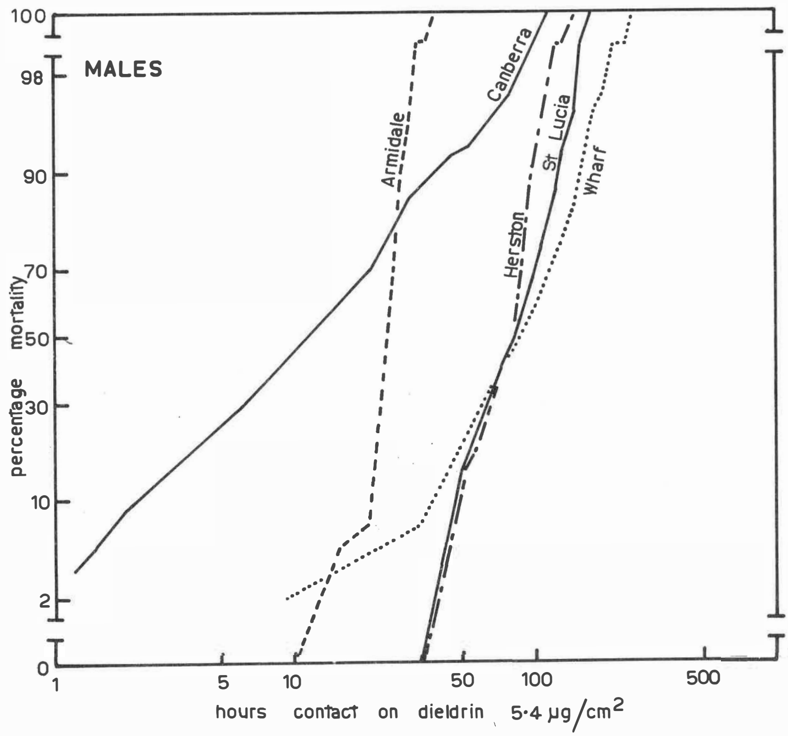

FIG. 7.—Exposure time-mortality lines for males of different strains of *B. germanica* obtained with dieldrin.

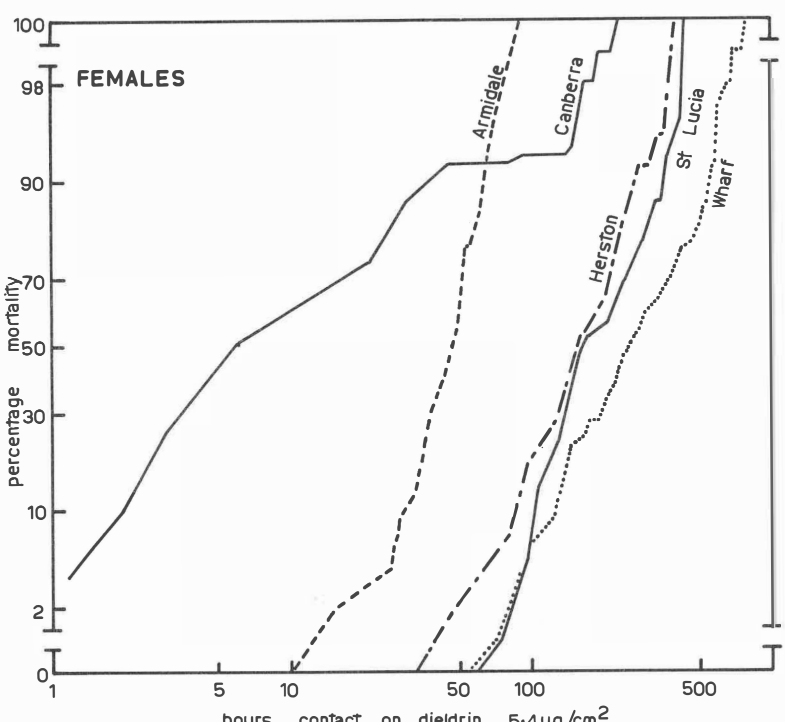

FIG. 8.—Exposure time-mortality lines for females of different strains of *B. germanica* obtained with dieldrin.

TABLE 1

EQUATIONS TO THE REGRESSION LINES, χ^2 VALUES AND STANDARD ERRORS OF THE LOG MEDIAN LETHAL DOSAGE (Sm) AND SLOPE (Sb) FOR THE DOSAGE-MORTALITY DATA OBTAINED FOR *B. germanica*.

STRAIN	MALE				FEMALE			
	y = a + bx	χ^2(d.f.)	Sm	Sb	y = a + bx	χ^2(d.f.)	Sm	Sb
dieldrin								
Armidale	y = 7.983 + 4.271x	*	*	*	y = 5.784 + 3.947x	0.42(1)	0.030	0.473
Canberra	y = 5.987 + 2.269x	0.23(2)	0.039	0.204	y = 4.898 + 1.266x	13.94(5)	0.091	0.103
St. Lucia	y = 3.498 + 1.632x	23.38(4)	0.113	0.127	y = 2.922 + 1.159x	4.28(4)	0.077	0.125
Herston	y = 3.956 + 1.377x	11.12(5)	0.076	0.102	y = 3.532 + 0.679x	5.61(7)	0.131	0.079
Wharf	y = 4.212 + 1.446x	3.64(4)	0.050	0.114	y = 2.308 + 1.338x	3.20(4)	0.064	0.127
lindane								
Armidale	y = 10.843 + 4.032x	*	*	*	y = 6.184 + 3.129x	0.29(1)	0.033	0.298
Canberra	y = 5.743 + 1.164x	9.54(6)	0.073	0.091	y = 4.133 + 1.995x	1.66(3)	0.042	0.174
St. Lucia	y = 4.387 + 1.623x	19.14(4)	0.103	0.128	y = 3.264 + 2.200x	10.16(2)	0.089	0.185
Herston	y = 4.004 + 1.853x	33.56(5)	0.149	0.166	y = 0.975 + 3.456x	*	*	*
Wharf	y = 3.797 + 2.463x	12.61(2)	0.093	0.215	y = 1.438 + 3.638x	3.90(1)	0.060	0.368
malathion								
Armidale	y = 2.046 + 3.637x	*	*	*	y = 0.989 + 3.309x	*	*	*
Canberra	y = 4.642 + 1.623x	1.25(4)	0.047	0.126	y = 3.946 + 1.131x	1.79(5)	0.067	0.115
St. Lucia	y = 4.714 + 2.143x	2.56(3)	0.040	0.185	y = 3.973 + 1.821x	1.72(4)	0.044	0.148
Herston	y = 5.316 + 2.653x	1.61(2)	0.036	0.241	y = 4.326 + 1.765x	0.65(3)	0.045	0.145
Wharf	y = 4.774 + 1.876x	0.87(3)	0.043	0.153	y = 4.168 + 1.552x	2.59(4)	0.049	0.130

* see text for explanation.

TABLE 2

THE INSECTICIDE SUSCEPTIBILITY OF STRAINS OF *B. germanica* BY TOPICAL APPLICATION; LD_{50} EXPRESSED AS μg PER COCKROACH AND μg PER GRAM OF TISSUE.

INSECTICIDE	STRAIN AND SEX									
	Armidale		Canberra		St. Lucia		Herston		Wharf	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
μg/cockroach										
dieldrin	0.20	0.63	0.37	1.20	8.32	62.02	5.72	145.11	3.51	102.67
lindane	0.04	0.42	0.23	2.72	2.38	6.15	3.44	14.60	3.08	9.53
malathion	6.49	16.30	1.66	8.55	1.36	3.66	0.76	2.41	1.32	3.43
μg/gram										
dieldrin	4.51	7.96	9.05	18.04	151.55	768.52	119.42	1575.58	72.67	1379.98
lindane	0.90	5.31	5.62	40.90	43.35	76.21	71.82	158.52	63.77	128.09
malathion	146.50	206.07	40.59	128.57	24.77	45.35	15.87	26.17	27.33	46.10

TABLE 3

WEIGHT, TOGETHER WITH STANDARD ERRORS, OF INDIVIDUALS OF THE VARIOUS STRAINS OF *B. germanica*.

STRAIN	WEIGHT IN MILLIGRAMS	
	Male	Female
Armidale	44.3 ± 0.5	79.1 ± 0.7
Canberra	40.9 ± 0.3	66.5 ± 1.1
St. Lucia	54.9 ± 0.6	80.7 ± 1.7
Herston	47.9 ± 0.4	92.1 ± 1.4
Wharf	48.3 ± 0.3	74.4 ± 0.8

TABLE 4

RESISTANCE RATIOS, BASED ON THE ARMIDALE STRAIN, OBTAINED BY TOPICAL APPLICATION ON A μg/COCKROACH AND A μg/GRAM BASIS AND BY THE CONTINUOUS EXPOSURE TEST AT THE 50 PER CENT RESPONSE LEVEL.

INSECTICIDE	STRAIN AND SEX							
	Canberra		St. Lucia		Herston		Wharf	
	♂	♀	♂	♀	♂	♀	♂	♀
topical application μg/cockroach								
dieldrin	1.8	1.9	41.6	98.4	28.6	230.3	17.6	162.9
lindane	5.8	6.5	59.5	14.6	86.0	34.8	77.0	22.7
malathion	0.3	0.5	0.2	0.2	0.1	0.2	0.2	0.2
topical application μg/gram								
dieldrin	2.0	2.3	33.6	96.6	26.5	197.9	16.1	173.4
lindane	6.2	7.7	48.2	14.4	79.8	29.8	70.8	24.1
malathion	0.3	0.6	0.2	0.2	0.1	0.1	0.2	0.2
continuous exposure								
dieldrin	4.6	1.8	32.0	40.6	30.0	35.7	32.1	58.5
lindane	1.6	2.4	5.1	11.4	10.0	12.4	9.4	14.6
malathion	0.5	0.7	0.3	0.3	0.3	0.4	0.3	0.5
diazinon	0.4	0.5	0.4	0.9	0.4	0.2	0.3	0.6
fenthion	1.9	2.1	2.3	2.2	0.9	1.2	1.8	2.2

The log exposure time-probit mortality data for dieldrin are shown graphed in Figures 7 and 8. Probit analyses of these data, and similar data for lindane and the OP insecticides malathion, diazinon and fenthion yielded the equations for the log exposure time-probit mortality regression (lt-p) lines and values of χ^2 shown in Table 5 and the LT_{50} values (hours) shown in Table 6. Armidale was the only strain in which no evidence of significant departure from a straight line relationship between mortality and exposure time was found.

With this continuous exposure test also the Armidale strain was the most susceptible to the organochlorine insecticides dieldrin and lindane and it was again used for the calculation of resistance ratios (Table 4). This again led to resistance ratios of less than one for malathion and also for diazinon but not for fenthion.

Statistical analyses showed that Armidale was significantly ($P = 0.05$) less susceptible to malathion than all other strains. The value of b in the equation to the lt-p line for Armidale males was significantly greater than b for the Canberra and Herston strains, while the b value for Armidale females was significantly less than

TABLE 5

EQUATIONS TO THE REGRESSION LINES, χ^2 VALUES AND STANDARD ERRORS OF THE LOG MEDIAN LETHAL EXPOSURE TIME (SM) AND SLOPE (SB) FOR THE EXPOSURE TIME-MORTALITY DATA OBTAINED FOR *B. germanica*.

STRAIN	MALE				FEMALE			
	y = a + bx	χ^2(d.f.)	Sm	Sb	y = a + bx	χ^2(d.f.)	Sm	Sb
dieldrin								
Armidale	y = −2.634 + 19.939x	0.47(2)	0.007	3.121	y = 0.638 + 6.734x	8.39(6)	0.007	0.477
Canberra	y = 2.604 + 2.303x	1.29(2)	0.038	0.186	y = 3.609 + 1.550x	15.41(6)	0.070	0.092
St. Lucia	y = −6.134 + 5.898x	4.54(5)	0.010	0.354	y = −5.881 + 4.824x	10.14(7)	0.010	0.246
Herston	y = −9.977 + 8.055x	17.87(2)	0.026	0.525	y = −5.857 + 4.934x	7.64(6)	0.010	0.282
Wharf	y = −2.149 + 3.787x	10.69(5)	0.220	0.199	y = −4.527 + 3.946x	12.07(7)	0.016	0.216
lindane								
Armidale	y = 9.376 + 8.803x	4.13(2)	0.013	0.683	y = 7.495 + 7.413x	3.01(3)	0.008	0.450
Canberra	y = 5.808 + 2.738x	21.51(7)	0.032	0.142	y = 4.907 + 1.723x	35.64(10)	0.045	0.098
St. Lucia	y = 4.312 + 3.216x	10.60(4)	0.033	0.188	y = 2.993 + 2.779x	52.01(6)	0.050	0.184
Herston	y = 0.498 + 8.911x	0.11(1)	0.008	0.721	y = 0.227 + 6.319x	2.95(3)	0.010	0.471
Wharf	y = 1.485 + 7.339x	12.24(4)	0.014	0.494	y = −0.179 + 6.258x	8.64(6)	0.008	0.345
malathion								
Armidale	y = 2.747 + 4.514x	6.29(7)	0.010	0.233	y = 3.472 + 3.338x	4.13(9)	0.013	0.179
Canberra	y = 4.283 + 3.069x	10.73(8)	0.018	0.179	y = 3.771 + 4.406x	4.84(6)	0.013	0.233
St. Lucia	y = 5.042 + 4.748x	1.71(5)	0.012	0.283	y = 5.139 + 4.936x	2.48(4)	0.012	0.298
Herston	y = 5.202 + 3.268x	0.84(4)	0.020	0.183	y = 4.843 + 2.973x	18.31(6)	0.037	0.179
Wharf	y = 4.864 + 4.796x	24.95(2)	0.056	0.356	y = 4.208 + 4.123x	0.53(4)	0.015	0.243
diazinon								
Armidale	y = 8.372 + 9.496x	3.79(3)	0.007	0.575	y = 8.418 + 9.608x	3.52(3)	0.007	0.584
Canberra	y = 10.664 + 7.694x	*	*	*	y = 8.791 + 5.851x	17.00(2)	0.038	0.484
St. Lucia	y = 7.994 + 4.910x	25.66(3)	0.040	0.364	y = 7.645 + 6.873x	38.08(4)	0.027	0.414
Herston	y = 7.045 + 2.906x	21.27(6)	0.072	0.198	y = 7.994 + 2.941x	2.40(3)	0.025	0.186
Wharf	y = 11.807 + 7.949x	*	*	*	y = 10.102 + 8.471x	1.34(1)	0.010	0.636
fenthion								
Armidale	y = 3.385 + 11.224x	0.91(4)	0.005	0.714	y = 2.119 + 15.319x	1.83(3)	0.004	0.944
Canberra	y = 1.959 + 7.328x	7.20(3)	0.013	0.452	y = −0.588 + 11.021x	6.88(2)	0.011	0.750
St. Lucia	y = −1.978 + 13.653x	0.44(2)	0.005	0.886	y = −0.830 + 11.119x	0.97(3)	0.006	0.809
Herston	y = 4.437 + 7.174x	15.63(3)	0.022	0.483	y = 2.529 + 9.095x	4.02(3)	0.007	0.564
Wharf	y = 2.402 + 6.373x	53.48(4)	0.035	0.487	y = −1.505 + 12.028x	1.53(3)	0.005	0.718

* see text for explanation.

TABLE 6

THE INSECTICIDE SUSCEPTIBILITY OF STRAINS OF *B. germanica* BY THE CONTINUOUS EXPOSURE METHOD: LT_{50} EXPRESSED IN HOURS.

INSECTICIDE	STRAIN AND SEX									
	Armidale		Canberra		St. Lucia		Herston		Wharf	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
dieldrin	2.41	4.44	10.98	7.89	77.19	180.20	72.35	158.60	77.26	259.63
lindane	0.32	0.46	0.51	1.13	1.64	5.27	3.20	5.69	3.01	6.73
malathion	3.16	2.87	1.71	1.90	0.98	0.94	0.87	1.13	1.07	1.56
diazinon	0.44	0.44	0.18	0.22	0.20	0.41	0.20	0.10	0.14	0.25
fenthion	1.39	1.54	2.60	3.21	3.24	3.34	1.20	1.87	2.56	3.47

the corresponding value for the Canberra, St. Lucia and Wharf strains.

Armidale males were significantly (P = 0.05) less susceptible to diazinon than Herston males and the females significantly less susceptible than females of the Canberra, Herston and Wharf strains. On the other hand Armidale was significantly more susceptible to fenthion than were the other strains.

An examination of the data in Tables 2 and 6, indicated that there were appreciable sexual differences, and to facilitate comparisons Table 7 presents the female LD_{50}: male LD_{50} and female LT_{50}: male LT_{50} ratios.

TABLE 7

RELATIVE SUSCEPTIBILITY OF THE SEXES OF *B. germanica* EXPRESSED AS THE RATIO OF THE FEMALE 50 PER CENT RESPONSE TO THE MALE 50 PER CENT RESPONSE.

INSECTICIDE	STRAIN				
	Armidale	Canberra	St. Lucia	Herston	Wharf
topical application μg/gram					
dieldrin	1.8	1.9	5.1	13.2	18.9
lindane	5.9	7.3	1.8	2.2	2.0
malathion	1.4	3.2	1.8	1.6	1.7
continuous exposure					
dieldrin	1.8	0.7	2.3	2.2	3.4
lindane	1.4	2.2	3.2	1.8	2.2
malathion	0.9	1.1	0.9	1.3	1.4
diazinon	1.0	1.2	2.1	0.5	1.8
fenthion	1.1	1.2	1.0	1.6	1.4

Although data on the rate of development was not an original intention of this work, from the records which were maintained the time for the development of adults from oothecae-bearing parent females was similar in all five strains, approximately nine weeks.

In all strains, female cockroaches were significantly heavier than male cockroaches (Table 3). While males of the resistant strains tended to be heavier than males of the laboratory strains, this tendency was much less evident with females.

Discussion

Of the two laboratory strains, Armidale and Canberra, the former was in all cases more susceptible than Canberra and the slope of the Armidale ld-p and lt-p lines was greater than the corresponding values for the Canberra strain. The acceptance of the Armidale strain as an organochlorine susceptible strain is justified by comparison of the data obtained for it with published continuous exposure data for dieldrin (Keller *et al.*, 1956; Brown & Wambera, 1961; Brown, 1966) and for lindane (Keller *et al.*; 1956) and with topical application data (Ishii & Sherman, 1965). The three field strains exhibited high levels of resistance to dieldrin and lower levels of resistance to lindane. The results substantiate the field evidence of poor control by cyclodiene insecticides at the Herston site. The levels of resistance to dieldrin and lindane are comparable with those reported for the highly chlordane resistant Manoa strain by Ishii & Sherman (1965).

With malathion no strain possessed an LD_{50} value as low as that reported for the susceptible Rutgers strain (Ishii & Sherman, 1965). The LT_{50} values for the St. Lucia and Herston strains do fall within the range of values reported by Johnston *et al.* (1964) for males of the FSH-susceptible strain and the LT_{50} values of all strains are within the range of values for susceptible strains reported to the World Health Organization.[1] Stapp (1964) reported male LT_{50} values for diazinon in the range 0.75-0.95 hours and Johnston *et al.* (1964) reported a value of 0.5 hours for susceptible FSH males. Based on these values all the strains employed in this study were susceptible to diazinon. The data for fenthion confirm that this insecticide also is an efficient material for the control of *B. germanica*.

The organochlorine insecticides dieldrin, chlordane and lindane were used extensively in Brisbane for cockroach control up to 1963-4, with dieldrin being the major insecticide employed, at least by pest control operators. Thus the resistance to lindane found in the field strains could have resulted from exposure to lindane or it could have arisen as a consequence of the more intensive use of dieldrin, since cross resistance between cyclodiene insecticides and lindane is well documented. Since 1963-4 OP insecticides e.g. malathion and carbamates e.g. arprocarb (Baygon) have either supplanted, or are used in conjunction with, the organochlorine insecticides following the development of resistance to these latter materials. While some populations of *B. germanica* in the United States of America have developed resistance to OP insecticides (Brown, 1966) there was no evidence of OP-resistance in the three field strains studied.

Compared with the susceptible Armidale strain, both sexes of the dieldrin resistant strains showed significantly enhanced susceptibility to malathion in the two toxicological tests. The slopes of the malathion ld-p lines for males and females of the Armidale strain were greater than for those of the other four strains but it was not possible to submit the data to statistical analysis. There was however no consistent trend in the slope values of the Armidale lt-p lines for malathion. Some of the dieldrin resistant strains also showed enhanced susceptibility to diazinon. There was no such tendency with fenthion; indeed with but one exception (Herston males) the resistant strains showed significantly decreased susceptibility. Brown (1961b) reports two instances of insect strains resistant to organochlorine insecticides being more susceptible than normal strains to malathion and one instance of a DDT resistant strain of the body louse, *Pediculus humanus humanus* L., being more susceptible to carbaryl than the normal strain.

It is a fairly common occurrence that females are more tolerant than males even if the greater weight of the female is taken into account. Females were more tolerant than males to topically applied dieldrin and this inter-sex difference was greater in the resistant strains (Table 7). This finding is in agreement with comparable data of

[1]Pal, R. and Kalra,R. L. 1965. Insecticide susceptibility of some insects of public health importance. Mimeographed document. Wld Hlth Org. Vector Control/123.65 23 pp. 3 figs.

Ishii & Sherman (1965). However, while females were also more tolerant than males to topically applied lindane, this inter-sex difference was greater in the susceptible strains. This finding differs from the data of Ishii & Sherman (1965). There was little variation in the relative susceptibility of the sexes with respect to the organophosphorus insecticides in the different strains.

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