Resistance to Lindane, Malathion and Fenitrothion in Coleopterous Pests of Stored Products in New Caledonia

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ABSTRACT

Field strains of *Tribolium castaneum, Rhyzopertha dominica, Oryzaephilus surinamensis, Sitophilus oryzae* and *S. zeamais* were studied for their response to lindane, malathion and fenitrothion. Bioassay tests were conducted using the insecticide-impregnated filter paper method according to the standard technique recommended by F.A.O. The synergist triphenyl phospate was used to check for malathion specific resistance.

Several strains of *T. castaneum* were resistant to lindane and malathion, with specific malathion resistance, *R. dominica* were susceptible to lindane but resistant to malathion and fenitrothion, *O. surinamensis* were diagnosed resistant to the three compounds tested. The last two species were non-malathion specific resistant. All *Sitophilus* spp. strains tested were susceptible to lindane, malathion and fenitrothion.

Tribolium castaneum (Herbst), *Rhyzopertha dominica* (F.), *Sitophilus oryzae* (L.), *S. zeamais* Motsch. and *Oryzaephilus surinamensis* (L.) are cosmopolitan insects and major pests of grain and stored products in New Caledonia (Brun and Chazeau 1980). The favorable tropical climate of New Caledonia allows the above-mentioned pests to develop throughout the year.

During the past decade all grain used on the Island was imported from overseas including Australia and used within a short period. Recently, however, many New Caledonian farmers and cooperative companies have altered their activities to meet the increasing local demand for grain crops, and several storage facilities have been built to provide continuous stock feed.

Malathion has been widely used to prevent insect infestations of stored grain in New Caledonia. Difficulties have been experienced in controlling some species of grain pests such as *T. castaneum* and *O. surinamensis* with malathion at La Tamoa and Bouloupari. Resistance to lindane and malathion were recorded in the major stored products pests in a global survey by Champ and Dyte (1976). Multiple organophosphate (OP) resistance of *R. dominica* was also recorded in Australia (Greening et al. 1974). Because the susceptibility of stored product pests from New Caledonia has not been included in the global survey, work was initiated by ORSTOM and BCRI to monitor and test the response of grain insects to insecticides and to measure the resistance levels in strains from New Caledonia. Data on five species of beetles are given here.

MATERIALS AND METHODS

Insect strains

Insect samples were collected from mills and grain storage facilities at Noumea, La Tamoa, Bouloupari and Pouembout (Table 1).

Cultures of *T. castaneum, R. dominica, S. oryzae, S. zeamais* and *O. surinamensis,* maintained in medium at 27°C and 60-70% relative humidity, were established from

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field samples. The diet used for *T. castaneum* was a mixture of finely-ground wholemeal flour and dried yeast powder (12:1 by weight). *R. dominica* and *S. oryzae* were cultured in whole wheat grain brought to approximately 12 percent moisture content after sterilization. *S. zeamais* were reared on maize grain at around 14% R.H. and *O. surinamensis* on rolled oats. Reference (susceptible) cultures were reared in a similar manner.

Bioassay procedure

Lindane, malathion and fenitrothion were technical grade, dissolved in Risella 17 oil. Adult insects were tested by exposure to insecticide-impregnated filter paper according to the standard technique recommended by FAO (Anon. 1980).

Survey data for each culture were obtained as follows. First, two batches of 40 individuals were exposed to diagnostic doses (DD) of each insecticide to discriminate against susceptible insects. The DD for lindane and malathion were based on FAO Method No. 15 (Anon. 1980). The DD for fenitrothion determined from dose response tests on susceptible strains of the five species were: 1% for *T. castaneum, R. dominica, S. oryzae, S. zeamais* and 2.5% for *O. surinamensis.* Samples with any adults surviving at DD's were recorded as resistant. Next, the level of resistance was measured in each field resistant strain. Two replicate batches of 40 adults were exposed to each of a graded series of lindane, malathion and fenitrothion concentrations. Tests of *T. castaneum, R. dominica* and *O. surinamensis,* for malathion specific resistance due to carboxyesterase, were conducted with 0.5%, 2.5% and 1% respectively, plus 10% triphenyl phosphate (TPP) dissolved in Risella 17 oil (Dyte and Rowlands 1968).

The exposure periods were: for lindane, 24 hours in all species; for malathion, malathion + TPP and fenitrothion 5 hours in *T. castaneum* and *O. surinamensis,* 6 hours in *Sitophilus* spp. and 24 hours in *R. dominica.*

Insects separated from the medium were tested at 25±1°C and 60±10% R.H. and kept under fluorescent lighting during the exposure period. The criterion of response was knockdown, defined as inability of insects to stand and walk. Dose response data were analyzed using the probit method of Finney (1971).

RESULTS AND DISCUSSION

The detection of lindane, malathion + TPP and fenitrothion resistances among different strains of *T. castaneum, R. dominica, S. oryzae, S. zeamais* and *O. surinamensis,* collected in New Caledonia in 1982, using the discriminating dose technique, is given in Table 1. Dose response data of resistant strains (KD50, KD99.9, RF and slope) are shown in Table 2. The slope values of all resistant field strains were lower than susceptible strain slope values.

Resistance to lindane and malathion was detected in five out of seven samples of *T. castaneum.* It is of interest that cultures resistant to lindane in *T. castaneum* were also resistant to malathion, even though these resistances are separate entities (Attia et al. 1981). Champ and Dyte (1976) reported that in all eight beetles studied, strains resistant to lindane were susceptible to malathion. Dyte et al. (1975) found that strains of *Oryzaephilus* spp. were resistant both to malathion and lindane.

All malathion resistant strains of *T. castaneum* tested were susceptible to malathion + TPP and fenitrothion. The use of the synergist TPP suggests that malathion resistance in *T. castaneum* is due to enhancement of the carboxyesterase activity, indicating specific malathion resistance (Dyte and Rowlands 1968). Strain

TABLE 1. Response data[a] from strains of *T. castaneum, R. dominica, S. oryzae, S. zeamais* and *O. surinamensis* adults exposed to discriminating doses (DD) of Lindane, Malathion, Malathion + TPP, and Fenitrothion.

Species, locality and date of collection	Strain N°	% knockdown at DD[b]			
		lindane	malathion	malathion + TPP	fenitrothion
T. castaneum					
Nouméa (Reference-June 82)	STC	100	100	100	100
Bouloupari (June 82)	TC1	35.3	0	99	100
Bouloupari (Nov. 82)	TC2	10.8	0	100	100
La Tamoa (June 82)	TC3	40.3	2.4	100	100
La Tamoa (Nov. 82)	TC4	36.8	0	100	100
La Tamoa (Nov. 82)	TC5	100	100	100	100
Nouméa (Nov. 82)	TC6	60	3.6	100	100
R. dominica					
Reference strain	CRD2[c]	100	100	100	100
La Tamoa (June 82)	RD1	100	85.1	79	80.6
S. oryzae					
Reference strain	SO267[c]	100	100	-	100
La Tamoa (June 82)	SO1	100	100	-	100
Nouméa (Nov. 82)	SO2	100	100	-	100
S. zeamais					
Reference strain	SZ[c]	100	100	-	100
Pouembout (Nov. 82)	SZ1	100	100	-	100
O. surinamensis					
Reference strain	OS22[c]	100	100	100	100
La Tamoa (July 82)	OS1	6.2	0	0	0

[a]Knockdown time assessed after appropriate exposure time:
- lindane 24 hrs. (all species).
- malathion and malathion + TPP 5 hrs. *(T. castaneum, O. surinamensis)*, 24 hrs. *(R. dominica)*, 6 hrs. *(Sitophilus* spp.).
- fenitrothion 5 hrs. *(T. cataneum, O. surinamensis)*, 24 hrs. *(R. dominica)*, 6 hrs. *Sitophilus* spp.

[b]Detection of resistance based on testing two replicates of 40 adults of each species. DD Discriminating dose for detection of resistance to:
- lindane was 0.5% *(T. castaneum)*, 0.1% *(R. dominca)*, 2% *(O. surinamensis)*, 0.2% *(Sitophilus* spp.).
- malathion was 0.5 *(T. castaneum)*, 2.5% *(R. dominica)*, 1% *(O. surinamensis)*, 1.5% *(Sitophilus* spp.).
- malathion + TPP, same concentration as malathion, plus 10% TPP.
- fenitrothion was 1% *(T. castaneum, R. dominica, Sitophilus* spp.) and 2.5% for *O. surinamensis.*

[c]Data for reference susceptible strains are obtained from Attia, BCRI.

TC3 was of low level resistance to lindane (×1.9), but showed a higher level of resistance to malathion (×33). Strain TC1 also had a high level of resistance to malathion (×40) (Table 2).

Malathion and fenitrothion resistance was detected in one sample of *R. dominica* (RD1), but was susceptible to lindane (Table 1). Strain RD1 showed a low level of resistance to malathion and fenitrothion (×3.6 and ×3.9 respetively) (Table 2). This strain was also resistant to malathion + TPP, indicating a non-specific malathion resistance.

The strain OS1 of *O. surinamensis* was diagnosed resistant to lindane, malathion and fenitrothion with resistance factors >×23, ×33 and ×25 respectively. This strain was also resistant to malathion + TPP at DD, indicating a non-specific malathion resistance (Tables 1 and 2). All samples of *S. oryzae* and *S. zeamais* were susceptible to lindane, malathion and fenitrothion.

TABLE 2. Dose response data, obtained by insecticide-impregnated paper, to resistant field strains of stored products pests.

Insecticides and species	Strain	Exposure time (hr)	KD50(%)	RF[c]	KD99.9(%)	RF[c]	Slope
Lindane							
T. castaneum	STC[a]	24	0.29	-	0.48	-	8
	TC3	24	0.55	1.9	6.1	12.7	3
O. surinamensis	OS22[b]	24	0.66	-	2.4	-	5
	OS1	24	>15	>23	-	-	-
Malathion							
T. castaneum	STC[a]	5	0.15	-	0.41	-	7
	TC1	5	6.0	40	>100	>243	2.3
	TC3	5	5.0	33	>100	>243	2.4
R. dominica	CRD2[b]	24	0.41	-	2.15	-	4.5
	RD1	24	1.5	3.6	13.5	6.2	3.2
O. surinamensis	OS22[b]	5	0.08	-	0.5	-	4
	OS1	5	2.7	33	24	48	3.6
Fenitrothion							
R. dominica	CRD2[b]	24	0.15	-	0.65	-	5
	RD1	24	0.58	3.9	5.4	8.3	3.5
O. surinamensis	OS22[b]	5	0.10	-	0.94	-	3.2
	OS1	5	2.5	25	22	23	3.1

[a]Reference strain from New Caledonia.
[b]Response data from reference susceptible strains tested at BCRI (Attia, unpublished data).
[c]RF Resistance factor = KD50 of resistant strain divided by KD50 of susceptible strain.
[d]KD50 (%) or KD99.9 (%) = Knockdown concentration for 50 or 99.9% of the population.

The development of resistance in stored products pests has been established in many overseas countries (Champ and Dyte 1976). These authors have also emphasized that resistant strains of grain insects could be transferred by shipment in the world trade, and this could account for the existence of resistant strains recorded in New Caledonia.

Fenitrothion can be used as an alternative insecticide to control high level malathion resistant strains of *T. castaneum* in New Caledonia. However, fenitrothion resistance was detected in malathion resistant strains of *T. castaneum* in Australia (Attia, unpublished data). Preliminary discriminating tests showed that *R. dominica* (RD1) which has a low level of resistance to malathion and fenitrothion, was suceptible to bioresmethrin. Thus, the mixture of fenitrothion plus bioresmethrin could be used to control the organophosphate resistant strain of *R. dominica* as this mixture is currently used as a grain protectant to control resistant strains of *R. dominica* in Australia (Greening 1981). The multiresistant strain of *O. surinamensis* (strain OS1) recorded, suggests that there is a need for further study of the cross resistance pattern, to seek for alternative chemicals.

The data obtained from strains of major stored products pests collected from the main storage facilities in New Caledonia show the resistance problem, particularly with organophosphate insecticides, is greater than expected. The information gathered at the ORSTOM Centre de Noumea has confirmed the results achieved previously at the Biological and Chemical Research Institute, Australia. The data support the current control strategies being employed in the New South Wales bulk handling system and reinforce the importance of resistance testing as a rational basis for chemical control of stored products pests.

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