DEVELOPMENT OF INSECT GROWTH REGULATORS AS GRAIN PROTECTANTS IN AUSTRALIA AND SOUTH-EAST ASIA

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At the previous meeting of this Working conference in Tel Aviv, I expressed the view that the speed at which insect growth regulators (IGR's) would be introduced and used in commercial practice as grain protectants would depend on the development of resistance to conventional pesticides, on the acceptability of their residues and on competitive pricing (Bengston, 1987). I retain that view and in this talk will update developments in our programs in regard to Australia and South-East Asia. I will concentrate on the development of methoprene and will leave discussion of other IGR's to my colleagues.

Grain protectants are widely used in Australia and to a lesser but still significant extent in SE Asia. In Australia, climatic conditions are such that most grain enters storage in a relatively dry and warm condition. The major crop is wheat and it typically enters storage at 10-12% grain moisture and 25-35°C grain temperature. In SE Asia, the marked alternation of wet and dry seasons combined in some areas with double cropping results in one crop being harvested in the wet season. At harvest, the moisture content in the major crops of rice and maize is high and significant quantities are dried artificially.

The work reported on wheat in Australia is carried out as part of the nation-wide co-operative research programme by the Australian Wheat Board's Working Party on Grain Protectants. Membership of the Working Party is summarised in Table I.

TABLE I. MEMBERSHIP OF THE AUSTRALIAN WHEAT BOARD'S WORKING PARTY ON GRAIN PROTECTANTS

AUSTRALIAN WHEAT BOARD'S WORKING PARTY ON GRAIN PROTECTANTS
Australian Wheat Board
CSIRO, Division of Entomology
Australian Department of Primary Industry and Energy
Grain Handling Authorities of Qld, NSW, Vic, SA, WA
Departments of Agriculture/Primary Industries of Qld, NSW, Vic, SA, WA

The work programme in regard to storage in SE Asia and by the Queensland Department of Primary Industries in regard to storage of paddy and maize is supported by the Australian Centre for International Agricultural Research (ACIAR). Organisations co-operating in the ACIAR programme are listed in Table II.

TABLE II. ORGANISATIONS CO-OPERATING IN THE ACIAR PROGRAM ON THE INTEGRATED USE OF PESTICIDES IN GRAIN STORAGE

ACIAR AUSTRALIAN CENTRE OF INTERNATIONAL AGRICULTURAL RESEARCH		
Queensland Department of Primary Industries		
Grain Handling Authorities	-	Australia
Naphire National Food Authority	} }	Philippines
Mardi LPN	} }	Malaysia
Department of Agriculture	-	Thailand

Studies by many authors have established that the response of major stored product pests to insect growth regulators differs widely according to species (Carter, 1975; Loschiavo, 1976; Kramer and McGregor, 1979; Mian and Mulla, 1982). Some typical data in relation to methoprene on wheat are summarised in Table III.

TABLE III. REDUCTION IN F_1 PROGENY OF *Rhyzopertha dominica* AND *Oryzaephilus surinamensis* BY METHOPRENE APPLIED TO WHEAT

Species	Dose Rate (mg kg^{-1})	F_1 Progeny Reduction (%)	Reference
Rhyzopertha dominica	1.0 1.0 0.125	99-100 99 100	Loschiavo, 1976 Amos and Williams, 1977 Bengston, 1987
Oryzaephilus surinamensis	0.1 1.0	100 100	Collins and Wilson, 1987 Caddick, 1990*

*personal communication

These data suggest *Sitophilus* spp. would not be controlled at application rates which are practicable in terms of cost and toxicology. Given the significance of *Sitophilus* spp. in storage of most raw cereal grains, this suggests that commercial use of methoprene would involve combination with another insecticide capable of controlling *Sitophilus* spp. My earlier paper reported successful field trials for the protection of wheat in 9 months storage with the combination of methoprene 1 mg kg^{-1} plus fenitrothion 12 mg kg^{-1}.

As is being reported by my colleagues (Daglish *et al.,* in press) the efficacy of insect growth regulators against *Sitophilus* spp. is markedly higher on milled rice than on raw cereals. Presumably this is related to the removal of the husk during milling and consequent penetration of the IGR into the kernel. Treatment of milled rice will not be further discussed in this paper. Currently chlorpyrifos-methyl, fenitrothion and pirimiphos-methyl are all registered for the control of *Sitophilus* in Australia.

<u>Relative Potency of Methoprene and S-Methoprene</u> Methoprene is a racemic mixture of the R and S isomers and most of the insecticidal activity is due to the S isomer. Future commercial formulations may involve either the resolved S isomer or the racemic mixture. Laboratory bioassays were carried out to compare the potency of methoprene with S-methoprene. The bioassays involved three strains of *Rhyzopertha dominica* representative of prevalent strains in Eastern Australia and including a susceptible and two organophosphate resistant strains. A graded series of six doses with three replicates of both compounds was used in each assay. Emulsifiable concentrate formulations were diluted with water and the diluted concentrate was pipetted into jars containing wheat of 11% grain moisture. The grain was tumbled for 10 minutes to ensure even distribution. This resulted in treated wheat at 12% grain moisture which was allowed to equilibrate at 25°C and 55% R.H. overnight. Fifty young adults (3-10 days old), were added to each jar containing 83 g treated wheat and were allowed to oviposit for 26 days at 25°C and 55% R.H. Parent insects were removed from the grain by sieving and the grain held at 30°C and 55% R.H. for 10 weeks before the number of F_1 progeny were counted and then for another 6 weeks when the F_2 progeny were counted. Data were analysed using the technique of Wadley's problem in probit analysis (Finney, 1971).

Data on the relative potencies are given in Table IV.

TABLE IV. RELATIVE POTENCY OF METHOPRENE TO S-METHOPRENE AGAINST *Rhyzopertha dominica* ON WHEAT

Strain	Resistance Status	Relative potency (5% fiducial limits)
QRD14	malathion susceptible	0.61 (0.59 - 0.63)
QRD 2	malathion specific	0.54 (0.52 - 0.56)
QRD63	organophosphate resistant	0.51 (0.49 - 0.54)

This suggested that an application rate of 0.6 mg kg^{-1} of S-methoprene should be biologically equivalent to 1 mg kg^{-1} of methoprene.

<u>Efficacy Under Commercial Conditions</u> Field studies were carried out in commercial storages. Bulk wheat was treated by spraying diluted insecticide prepared from emulsifiable concentrate formulations at the rate of 1 L per tonne during intake to concrete silos. Following intake, a composite sample of treated grain was prepared from grain aspirated at 12 sample points 2 m below the grain surface using a vacuum sampler. Subsamples were transferred to tins and sealed for transport to co-operating laboratories. Chemical assays and bioassays were carried out on these subsamples. Routine inspections of the grain were carried out by the grain handling authorities but no natural infestations were observed.

<u>Field Experiments with S-Methoprene</u> Data on the treatment of grain with S-methoprene and fenitrothion are given in Table V.

TABLE V. STORAGES AND GRAIN TREATED WITH S-METHOPRENE 0.6 MG KG^{-1} PLUS FENITROTHION 12 MG KG^{-1}

Site	Date Treated	Quantity (t)	Temperature During Storage	Grain Moisture
Billimari, NSW	9 February 87	810	24-32°C	11.9-12.3%
North Fremantle, WA	21 January 87	500	18-24°C	8.4-8.9%

Data on residues meaned from results in three laboratories are given in Table VI.

TABLE VI. RESIDUES OF S-METHOPRENE IN GRAIN TREATED WITH S-METHOPRENE 0.6 MG KG^{-1} PLUS FENITROTHION 12 MG KG^{-1}

Site	Calculated Application Rate	Approx. time after spray application (months)					
		0	1½	3	4½	6	9
Billimari, NSW	0.59 + 11.7	0.49	0.37	0.35	0.33	0.34	0.35
North Fremantle, WA	0.51 + 8.5	0.38	0.31	0.27	0.32	0.32	0.26

Initial deposits measured analytically were around 80% of the calculated application rate and this is consistent with experience in commercial storage in Australia. Residues were quite persistent and declined only 20% during 9 months storage.

Typical examples of data from laboratory bioassays with *Rhyzopertha dominica* are given in Table VII and with *Oryzaephilus surinamensis* in Table VIII.

TABLE VII. LABORATORY BIOASSAYS OF *Rhyzopertha dominica* STRAIN QRD63 IN WHEAT TREATED WITH S-METHOPRENE 0.6 MG KG^{-1} PLUS FENITROTHION 12 MG KG^{-1} AND STORED IN CONCRETE SILOS AT BILLIMARI NSW, PRIOR TO ASSAY

Time after treatment (months)	Parent response after 26 days (%)	Reduction in F_1 progeny (%)	Reduction in F_2 progeny (%)
0	100	99.8	100
1½	7.4	99.6	100
3	0.0	99.9	100
4½	6.4	99.8	100
6	18.1	99.9	100
8½	2.9	100	100

TABLE VIII. LABORATORY BIOASSAYS OF *Oryzaephilus surinamensis* STRAIN QOS42 IN WHEAT TREATED WITH S-METHOPRENE 0.6 MG KG^{-1} PLUS FENITROTHION 12 MG KG^{-1} AND STORED IN CONCRETE SILOS AT BILLIMARI NSW, PRIOR TO ASSAY

Time after treatment (months)	Parent response after 26 days (%)	Reduction in F_1 progeny (%)	Reduction in F_2 progeny (%)
0	74.3	100	100
1½	14.1	100	100
3	0.0	95.8	100
4½	0.0	-	100
6	0.0	100	100
8½	0.0	100	100

Data for both species had similar trends. Response of parents declined rapidly after the initial bioassay reflecting the efficacy of fenitrothion against these strains. Reduction in F_1 progeny was almost but not quite 100% and it is not possible to distinguish absolutely between surviving parents and actual F_1 progeny. Reduction in F_2 progeny was complete.

No natural infestation was observed during the 9 months storage.

In 1987-88, field experiments were carried out with combinations of methoprene 1 mg kg^{-1} with chlorpyrifos-methyl in five silos and with malathion in one silo. In 1988-89, experiments involved combinations of methoprene with malathion in three silos. Bioassays gave results similar to those in Tables VII and VIII and no natural infestation was observed in any of the eight silos during the 9 months storage.

Laboratory studies have been carried out on paddy and maize in SE Asia and have given similar results to those in Australia. Methoprene has been cleared for use as a grain protectant by federal authorities in Australia and has been registered in some states. It has been used successfully on 100 000 tonnes of wheat in commercial storage. In 1989, draft maximum residue limits of methoprene on raw cereals were advanced by the Codex Alimentarius Commission to Step 8 of its process.

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