INSECT GROWTH REGULATORS AS PROTECTANTS AGAINST SOME INSECT PESTS OF CEREALS AND LEGUMES.

G.J. DAGLISH and P.R. SAMSON[1]

Entomology Branch, Dept. of Primary Industries, Meiers Rd, Indooroopilly, 4068, Australia.

[1] Present Address: Bureau of Sugar Experiment Stations, Bundaberg, 4670, Australia.

ABSTRACT

Results are presented for experiments evaluating three insect growth regulators (IGRs)- methoprene, fenoxycarb and diflubenzuron- against some insect pests of cereals and legumes. Activity was assessed according to the number of progeny produced in treated and untreated grain. Five species of insect were used: *Rhyzopertha dominica*, *Sitophilus oryzae*, *S. zeamais*, *Acanthoscelides obtectus*, and *Callosobruchus phaseoli*. Resistant strains of the first three species and susceptible strains of the two other species were used to test efficacy of these compounds on a range of grains.

Methoprene applied to wheat, maize or paddy was more effective against *R. dominica* than the other IGRs. Methoprene was not effective against *Sitophilus* species. Fenoxycarb and diflubenzuron were much more potent against *S. oryzae* when applied to white rice than when applied to wheat, maize or paddy. None of the compounds was effective at low rates against *A. obtectus* infesting navy beans. Fenoxycarb applied to mung beans gave much greater control of *C. phaseoli* than either methoprene or diflubenzuron.

The results show that activities of IGRs depends on the species of insect and type of grain. These compounds may be useful in protecting some cereals and legumes in commercial storage, in combination with other insecticides.

INTRODUCTION

The use of residual insecticides as part of grain protection programmes will continue for the foreseeable future (Champ and Ryland 1987). Currently available insecticides include conventional insecticides and insect growth regulators (IGRs). Most conventional insecticides are neurotoxic. IGRs, in contrast, disrupt insect growth and development (Retnakaran *et al.* 1985), and have low mammalian toxicity (Anon. 1987). *Rhyzopertha dominica* F., *Sitophilus oryzae* L., and *S. zeamais* (Motschulsky) are among the most serious pest of stored cereals in Australia (Champ and Dyte 1976), and the bruchids *Acanthoscelides obtectus* Say and *Callosobruchus phaseoli* (Gyll.) are pests of stored navy beans and mung beans, respectively. In Australia methoprene is being trialled in commercial storage specifically against *R. dominica* (Bengston 1987), but research on other IGRs as potential grain protectants is less advanced.

We present results of experiments on the juvenile hormone analogues methoprene and fenoxycarb, the chitin synthetase inhibitor diflubenzuron against these insect pests of stored cereals and legumes in Queensland, Australia. The experiments were designed to identify potential grain protectants and to estimate application rates for control in commercial storage. Cross-resistance to IGRs has been reported (Dyte 1972), therefore representative resistant strains were used where appropriate.

MATERIALS AND METHODS

IGRs, grains and test insects

A miscible oil formulation of methoprene (500g A.I. litre^{-1}), and emulsifiable concentrates of fenoxycarb (125g A.I. litre^{-1}) and diflubenzuron (480g A.I. litre^{-1}) were used for evaluations.

Bioassays were carried out using the following species and strains of insect: *R. dominica* (multi-resistant), *S. oryzae* (multi-resistant), *S. zeamais* (deltamethrin-resistant), *A. obtectus* (susceptible) and *C. phaseoli* (susceptible). The grains used were: wheat, maize, paddy rice, white rice, navy beans, and mung beans. Grains were stored at 30°C, 70% R.H. to attain equilibrium moisture content, before being treated with IGRs.

Treatment and storage of grain

Grain was treated in glass jars. IGR diluted in water to the appropriate concentration was pipetted onto the glass immediately above the grain surface, at a rate of 1 ml kg^{-1} of grain. Jars were sealed with aluminium foil and plastic lids, shaken by hand briefly and tumbled mechanically for 5 minutes. Jars containing grain were stored overnight at 25°C, 70% R.H. for bioassays of fresh deposits, or at 30°C, 70% R.H. for bioassays of grain during storage.

Bioassay procedures

IGRs were assessed as fresh deposits in which adults were added to grain 1 day after treatment, and during storage in which adults were added to grain after various periods of storage (up to 48 weeks) after treatment. IGRs which were effective as fresh deposits were tested further during storage. For fresh deposit tests, IGRs were applied to 83g of grain (N=3) at up to seven rates plus an untreated control, and bioassays were begun the following day. For aged residue tests, IGRs were applied to 2kg of grain (N=1) at six or seven rates plus an untreated control, and samples were taken for bioassay (N=3) after 0 (1 day), 6, 12, 18, 24, 36, and in some cases 48 weeks.

In both types of bioassay 50 adults were added to each jar. *R. dominica* and *Sitophilus* adults were 1-3 weeks old when added to grain, while the short-lived bruchids (*A. obtectus* and *C. phaseoli*) were 0-3 days old. Jars containing *C. phaseoli* were kept at 30°C for 12 days then the adults were sieved from the grain. Other jars were kept at 25°C for 12 (*A. obtectus*) or 26 days when adults were removed. After adults were removed jars containing *R. dominica* were transferred to 30°C. Adult progeny of *R. dominica* and *Sitophilus* were assessed at 10 and 16 weeks, progeny of *A. obtectus* at 7 and 13 weeks, and progeny of *C. phaseoli* at 5 and 9 weeks. Probit analysis of the Wadley's problem type was used to determine the relationship between number of F_1 progeny and concentration of IGR (Finney 1971). Minimum effective application rates for various periods of protection were determined from F_2 data.

RESULTS

Methoprene was more active than fenoxycarb or diflubenzuron against *R. dominica* infesting wheat, maize and paddy (Table I). Maize and paddy treated with methoprene, fenoxycarb or diflubenzuron were assayed with *R. dominica* after various periods of storage up to 48 wk. Methoprene controlled progeny in maize and paddy at lower rates than did either of the other two IGRs (Table V).

Preliminary assays on wheat against *S. oryzae* and *S. zeamais*, showed that methoprene was ineffective against either species. For example, methoprene applied at 300 mg kg^{-1} resulted in only 15 and 20% progeny reduction respectively. The results also showed that *S. oryzae* was more difficult to control than *S. zeamais* using either fenoxycarb or diflubenzuron (Table II), therefore further assays used *S. oryzae* only. Assays of fenoxycarb or diflubenzuron on wheat, maize, paddy, and white rice, showed that activities of these IGRs was much greater on white rice than on the other grains (Table III). Subsequent assays showed that either fenoxycarb or diflubenzuron applied at the rate of 1 mg kg^{-1} to white rice could prevent production of progeny by *S. oryzae* for 48 wk of storage (Table V).

Table I. Effects of methoprene, fenoxycarb and diflubenzuron applied to wheat, maize and paddy on F_1 progeny of *R. dominica* (from Samson *et al.* 1990). Rates in mg kg^{-1}

Grain	LC_{50} (95% limits)	$LC_{99.9}$	Slope±S.E.
	Methoprene		
Wheat	0.026 (0.022-0.029)	0.24	3.17±0.081
Maize	0.028 (0.014-0.045)	7.9	1.26±0.075
Paddy	0.026 (0.021-0.032)	0.27	3.06±0.129
	Fenoxycarb		
Wheat	0.051 (0.037-0.066)	4.3	1.61±0.051
Maize	0.0078 (0.0038-0.014)	180	0.71±0.036
Paddy	0.29 (0.22-0.38)	16	1.79±0.085
	Diflubenzuron		
Wheat	0.011 (0.0040-0.021)	7.4	1.09±0.026
Maize	0.044 (0.026-0.065)	17	1.20±0.086
Paddy	0.063 (0.017-0.16)	515	0.79±0.030

Table II. Effects of methoprene, fenoxycarb and diflubenzuron applied to wheat against F_1 progeny of *S. oryzae* and *S. zeamais*. Rates in mg kg^{-1}.

Insect	IGR	LC_{50} (95% limits)	$LC_{99.9}$	Slope±S.E.
S. oryzae	Fenoxycarb	7.1 (5.4-8.8)	510	1.7±0.03
S. zeamais	Fenoxycarb	0.56 (0.31-0.85)	110	1.4±0.03
S. oryzae	Diflubenzuron	0.26 (0.14-0.40)	150	1.1±0.03
S. zeamais	Diflubenzuron	0.26 (0.22-0.30)	26	1.6±0.05

Table III. Effects of fenoxycarb and diflubenzuron applied to wheat, maize, paddy and white rice on F_1 progeny of *S. oryzae*. Rates in mg kg^{-1}.

Grain	LC_{50} (95% limits)	$LC_{99.9}$	Slope±S.E.
	Fenoxycarb		
Wheat	6.2 (4.6-7.8)	240	1.9±0.04
Maize	5.9 (4.1-7.7)	440	1.7±0.06
Paddy	11 (1.7-22)	760	1.7±0.47
White Rice	0.088 (0.069-0.11)	0.65	3.6±0.24
	Diflubenzuron		
Wheat	0.65 (0.43-0.91)	49	1.6±0.02
Maize	0.38 (0.18-0.66)	70	1.4±0.04
Paddy	0.98 (0.43-1.7)	88	1.6±0.15
White Rice	Complete control at 0.3		

Table IV. Effects of methoprene, fenoxycarb and diflubenzuron against F_1 progeny of *A. obtectus* (in navy beans) and *C. phaseoli* (in mung beans). Rates in mg kg^{-1}.

IGR	LC_{50} (95% limits)	$LC_{99.9}$	Slope±S.E.
	A. obtectus		
Methoprene	8.5 (4.3-14)	8700	1.03±0.041
Fenoxycarb	0.01 (0-0.12)	53000	0.47±0.032
Diflubenzuron	0.90 (0.45-1.5)	510	1.12±0.036
	C. phaseoli		
Methoprene	24 (14-33)	230	3.14±0.227
Fenoxycarb	0.020 (0.0080-0.025)	1.2	1.67±0.168
Diflubenzuron	1.5 (0.60-2.6)	270	1.36±0.081

Table V. Minimum effective application rates of methoprene, fenoxycarb and diflubenzuron, against *R. dominica*[1], *S. oryzae*, and *C. phaseoli* on various grains. Periods of protection given in weeks.

IGR	Grain	0 wk	12 wk	24 wk	36 wk	48 wk
			R. dominica			
Methoprene	Maize	1-2	2-4	0.5-1	>4	1-2
	Paddy	0.15-0.5	0.05-0.15	0.05-0.15	0.05-0.15	-
Fenoxycarb	Maize	>10	2-5	>10	5-10	2-5
	Paddy	1-2	5-10	2-5	2-5	-
Diflubenzuron	Maize	2-5	0.3-1	1-2	2-5	2-5
	Paddy	2-5	0.3-1	5-10	2-5	-
			S. oryzae			
Fenoxycarb	White rice	0.5-1	0.5-1	0.5-1	0.5-1	0.5-1
Diflubenzuron	White rice	0.25-0.5	0.5-1	0.25-0.5	1-2	0.5-1
			C. phaseoli			
Fenoxycarb	Mung bean	0.75-1.5	0.25-0.5	0.25-0.5	0.25-0.5	-

[1] From Samson *et al.* (1990).

None of the IGRs was effective at low rates against *A. obtectus* in navy beans (Table IV). On mung beans fenoxycarb was much more active against *C. phaseoli* than methoprene or diflubenzuron (Table IV). The results of stored mung beans showed that an application rate of 0.5 mg kg^{-1} would prevent progeny for 36 wk of storage (Table V).

DISCUSSION

Activities of the IGRs were affected by insect species and grain type. Methoprene had high potency against *R. dominica* but low potency against the other species. Low activity of methoprene against *Sitophilus* species has been found in other studies (e.g. McGregor and Kramer 1975, Strong and Diekman 1973). Fenoxycarb showed greatest activity against *S. oryzae* in white rice and *C. phaseoli* in mung beans. Diflubenzuron was most active against *S. oryzae* in white rice. These results highlight the high specificity of action of IGRs.

Fenoxycarb and diflubenzuron were more potent against *S. oryzae* in white rice than in paddy. This difference probably is related to the outer grain layers which are present in paddy but absent in white rice. *Sitophilus* immatures develop inside the kernel, so control of progeny will depend on the amount of residue penetrating inside the kernel.

All compounds maintained activity almost unchanged during storage. This is consistent with other studies on IGRs (e.g. Kramer *et al.* 1985, Cogburn 1988, Mian and Mulla 1983) but contrasts with results for some of the conventional insecticides (Samson and Parker 1989, Samson *et al.* 1989).

CONCLUSION

Activities of methoprene, fenoxycarb and diflubenzuron varied greatly depending on the species of insect and type of grain used. The results of long term experiments showed that activity of each of the IGRs remained relatively unchanged during storage of up to 48 wk. This probably reflects the stability of the residues. IGRs are unsuitable for disinfesting grain because they act mainly on immature stages of insects. Therefore, they may need to be integrated with other practices, where the presence of adults is not acceptable.

ACKNOWLEDGEMENTS

This research was funded by the Australian Centre for International Agricultural Research (ACIAR).

REFERENCES

Anon. (1987) *The Agrichemicals Handbook*, Royal Society of Chemistry, University of Nottingham, U.K.

Bengston, M. (1987) Insect growth regulators. *4th Int. Work. Conf. Stored-Prod. Protection*, Tel Aviv, Israel, 1986, pp. 35-46.

Champ, B.R. and Dyte, C.E. (1976) *Report of the FAO global survey of pesticide susceptibility of stored grain pests.* FAO Plant Prod. Prot. Series No. 5, Rome, FAO.

Champ, B.R. and Ryland, G. (1987) The role of residual pesticides in stored-product insect control. *4th Int. Work. Conf. Stored-Prod. Protection,* Tel Aviv, Israel, 1986, pp. 281-287.

Cogburn, R.R. (1988) Fenoxycarb as a long-term protectant for stored rough rice. *J. econ. Ent.* **81**, 722-726.

Dyte, C.E. (1972) Resistance to a synthetic juvenile hormone in a strain of the flour beetle, *Tribolium castaneum. Nature.* **238**, 48-49.

Finney, D.J. (1971). *Probit Analysis.* 3rd Ed., Cambridge University Press, London.

Kramer, K.J., Hendricks, L.H., Wojciak, J.H. and Fyler, J. (1985) Evaluation of fenoxycarb, *Bacillus thuringiensis*, and malathion as grain protectants in small bins. *J. econ. Ent.* **78**, 632-636.

McGregor, H.E. and Kramer, K.J. (1975) Activity of the insect growth regulators hydroprene and methoprene on wheat and corn against several stored-grain insects. *J. econ. Ent.* **68**, 668-670.

Mian, L.S. and Mulla, M.S. (1983) Persistence of three IGRs in stored wheat. *J. econ. Ent.* **76**, 622-625.

Retnakaran, A., Garnett, J. and Ennis, T. (1985) Insect growth regulators. *Comprehensive Insect Physiology, Biochemistry, and Pharmacology,* (Edited by G.A. Kerkut and L.I. Gilbert), Vol. 12, Insect Control, Pergamon Press, Oxford, U.K.

Samson, P.R. and Parker, R.J. (1989) Laboratory studies on protectants for control of coleoptera in maize. *J. stored Prod. Res.* **25**, 49-55.

Samson, P.R., Parker, R.J. and Jones, A.L. (1989) Laboratory studies on protectants for control of *Sitophilus oryzae* (Coleoptera: Curculionidae) and *Rhyzopertha dominica* (Coleoptera: Bostrichidae) in paddy rice. *J. stored Prod. Res.* **25**, 39-48.

Samson, P.R., Parker, R.J., and Hall, E.A. (1990) Efficacy of the insect growth regulators methoprene, fenoxycarb and diflubenzuron against *Rhyzopertha dominica* (F.) (Coleoptera: Bostrichidae) on maize and paddy rice. *J. stored Prod. Res.* (in press).

Strong, R.G. and Diekmen, J. (1973) Comparative effectiveness of fifteen insect growth regulators against several pests of stored products. *J. econ. Ent.* **66**, 1167-1173.

LES REGULATEURS DE CROISSANCE EN TANT QU'AGENTS PROTECTEURS CONTRE CERTAINS INSECTES RAVAGEURS DES CEREALES ET DES LEGUMINEUSES

G.J. DAGLISH et P.R. SAMSON (1)

Entomology Branch, Department of Primary Industries,
Meiers Road, Indooroopilly Q 4068, Australia
(1) Adresse actuelle : Bureau of Sugar Experiment Stations
Bundareg Q 4670, Australia

RESUME

Trois régulateurs de la croissance des insectes : méthoprène, fénoxycarb et diflubenzuron, ont été essayés sur certains insectes déprédateurs des céréales et des légumineuses. L'activité a été mesurée selon le nombre de descendants produit sur du grain traité et non traité. Les trois régulateurs ont été efficaces à des doses acceptables sur *Rhyzopertha dominica* sur blé, maïs et riz paddy. Le fénoxycarb et le diflubenzuron ont éliminé les espèces de *Sitophilus* sur le riz blanc mais pas sur le blé, le maïs ou le riz paddy. Le méthoprène n'a été efficace sur *Sitophilus* pour aucune des céréales utilisées. Aucun régulateur n'a été efficace contre *Acanthoscelides obtectus* sur le haricot mungo. Les résultats montrent que l'action des régulateurs dépend de l'espèce d'insecte et du type de grain. Ces composés peuvent s'avérer utiles dans la protection de certaines céréales et légumineuses dans les stocks du commerce à condition d'être utilisés en combinaison avec d'autres insecticides.