Insect growth regulators for the control of stored-grain insect pests

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Abstract

Four insect growth regulators (IGRs): three chitin inhibitors-flufenoxuron, hexaflumuron and triflumuron, and the juvenile hormone analog (JHA) methoprene, were evaluated for their residual activity on stored maize for twelve months against *Prostephanus truncatus, Rhyzopertha dominica* and *Sitophilus zeamais*. The three chitin inhibitors were tested at three dosage levels, whilst methoprene was tested at 5 mg/kg. Treatments of 5 mg/kg flufenoxuron or 5 mg/kg hexaflumuron produced greater than 90% control over 12 months against the three insect species. Methoprene at 5 mg/kg was ineffective against *S. zeamais*, although it showed good residual action against *R. dominica* and *P. truncatus*. Triflumuron at 10 mg/kg produced greater than 90% control of *R. dominica* and *S. zeamais* over the 12-month period, however the effect against *P. truncatus* was less consistent, although at 12 months 90% control was achieved.

Introduction

High non-target toxicity, persistence and a wide spectrum of activity are characteristics which have led, in recent years, to the withdrawal of many conventional insecticides. Highly persistent compounds were found to accumulate in food chains affecting a wide range of wildlife. The widespread use of conventional insecticides has also led to the development of resistance amongst some insect pest species. Consequently, there is a need to introduce alternative compounds which are less persistent and more pest-specific. Of those currently identified, substances which act on biochemical processes found only in insects appear to be suitable and effective replacements for conventional insecticides.

Insect growth regulators (IGRs) are compounds which interfere with insect metabolism in a manner that affects growth. IGRs are arthropod-specific and, as they are not neurotoxic, appear to have less potential to be harmful to man and other vertebrates than conventional insecticides. They are lethal to eggs, larvae and pupae (Mian and Mulla 1982). They can inhibit the formation of chitin required to make a new cuticle at each moult. They can also replace or disrupt the production of juvenile hormone, which controls insect metamorphosis and development. In general IGRs do not kill adult insects but prevent juvenile stages from completing their development. Control of an insect population with IGRs is therefore a gradual process. The percentage control of adult emergence reflects the cumulative mortality sustained by all developmental stages i.e. egg, larvae, pupae and adult (Mian et al. 1990).

The object of the experimental program reported here was to investigate the efficacy of four IGRs (methoprene, triflumuron, hexaflumuron and flufenoxuron as control agents against three insect pests of stored products common to tropical environments.

Materials and Methods

Methoprene is a synthetic analogue of naturally-occurring insect juvenile hormone. Its mode of action varies between insect species: typical effects include inhibited oviposition and metamorphosis, increased time for larval development and production of super-larvae. Methoprene has been registered by the Joint Meeting on Pesticide Residues (JMPR) of the WHO and FAO for application to cereal grains; a maximum residue limit of 5 mg/kg is permissible.

Triflumuron is a benzoylphenylurea, which acts by inhibiting chitin synthesis in larvae or, alternatively, interfering with egg hatching. It and hexaflumuron, a chitin inhibitor with a broader spectrum of biological activity, have been registered for use against agricultural pests, including Lepidoptera, Coleoptera, Diptera and Hymenoptera, in various countries in Europe, South America, Africa, Latin America, Australia and South-East Asia (Fox 1990).

Flufenoxuron, another inhibitor of chitin formation, is an acylurea shown to be effective against a range of pre-harvest insect and mite pests on maize, cotton, vegetables and top fruits (Fox 1990). It has been launched in several countries and submitted for registration for use in several major markets (Fox 1990).

Technical grade compounds were used in the experiments. The sources and application rates are shown below:

IGR	Purity of technical compound (%)	Concentrations tested (mg/kg)
Flufenoxuron (Shell/Cyanamid)	97.8	2,5,10
Triflumuron (Bayer AG.)	99.45	1,10,15
Hexaflumuron (Dow Elanco)	99.7	1,5,15
Methoprene (British Greyhound)	95	5

Organically grown and insecticide-free whole maize kernels were used throughout the test program. The grain was sieved and hand-sorted to remove brokens and foreign matter. Batches (500 g) of prepared maize were then sealed into plastic bags for storage until required for use in the trials.

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Treatments were applied in acetone solution: for each concentration, the required amount of IGR was diluted in 250 mL of acetone. Each 500 g batch of maize was placed in a round bottomed flask and 250 mL of solution was added. The flask was attached to a rotary evaporator and mixed for 10 minutes to ensure even distribution of the chemical and then placed under vacuum at 35–40°C until all the solvent was removed; this took a further 20 minutes. Controls were treated with acetone only. The treated batches were then transferred to large containers, which were placed in a fume cupboard for 48 hours to allow final evaporation of acetone. For storage, the maize was packed into 2 L containers, which were fitted with black filter paper lids, sealed with paraffin wax. These containers were kept at 30 ±1°C and 70 ± 5% relative humidity (r.h.).

Prostephanus truncatus (Horn) of Tanzanian origin, *Rhyzopertha dominica* (Fabricius) and *Sitophilus zeamais* (Motschulsky), obtained from insecticide-susceptible laboratory cultures, were used in the trials. Immediately after treatment, and then at intervals of 3, 6, 9 and 12 months, fifty 1–2 week old unsexed adults were added to 50 g of treated maize. After 7 days live adults were recovered and their numbers recorded. Numbers of F_1 progeny were recorded before being transferred to clean maize (treated at the same application rate) at a density of 1 adult/gram. F_2 numbers were then recorded. Bioassays were replicated three times and conducted at 30±1°C and 70±5% r.h.

Results

The mortality of the parent adults of all three species exposed to treated grain for 1 week, was less than 10%. This indicated that, at the dosages examined, these four IGRs had no direct effect on adult mortality. The effect of IGRs on the production of F_1 progeny is shown in Figures 1–3. The results are expressed as the percentage suppression of progeny on treated grain compared with those that emerged on control grain. In general, treatments of 5 mg/kg flufenoxuron, 5 mg/kg hexaflumuron and 10 mg/kg triflumuron were effective at producing greater than 90% control over 12 months. Higher doses produced almost 100% control. Of the four IGRs tested, flufenoxuron was consistently the most effective. Methoprene at 5 mg/kg was ineffective against *S. zeamais*; however, it showed good residual action against *R. dominica* and *P. truncatus*. The percentage control of F_2 progeny is shown in Figures 4–6. In general, exposure of *P. truncatus, S. zeamais* or *R. dominica* to any tested treatment caused complete control of F_2 progeny; there was little emergence, especially at or beyond 6 months after treatment (with the exception of *S. zeamais* which exhibited tolerance to methoprene). The lowest dosages of flufenoxuron, triflumuron and hexaflumuron were seen to offer a lesser degree of control of F_2 progeny of *P. truncatus*. In particular, all doses of triflumuron and hexaflumuron were significantly less effective at 3 months after treatment.

Discussion

The persistence of flufenoxuron, triflumuron and hexaflumuron against storage insect pests of durable commodities has been demonstrated previously (Mian and Mulla 1982; Ammar 1988). However, this is the first occasion where their residual effectiveness against *P. truncatus* has been examined. Flufenoxuron at 5 mg/kg has been found to produce greater than 95% control of F_1 adults of *P. truncatus, R. dominica* and *S. zeamais* for 12 months. Other studies have shown that

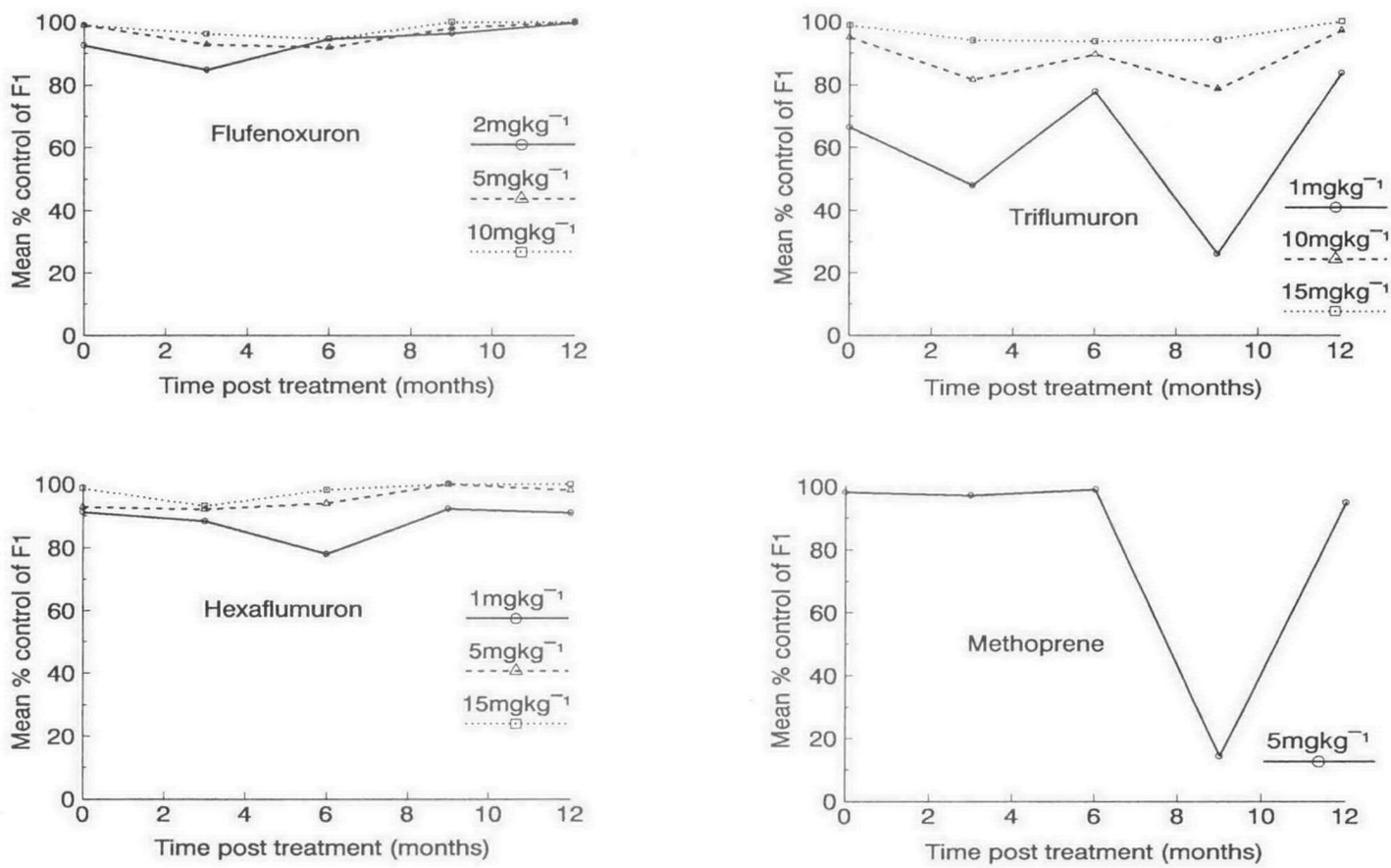


Fig. 1. Mean percentage control of F_1 progeny of *P. truncatus* on treated maize.

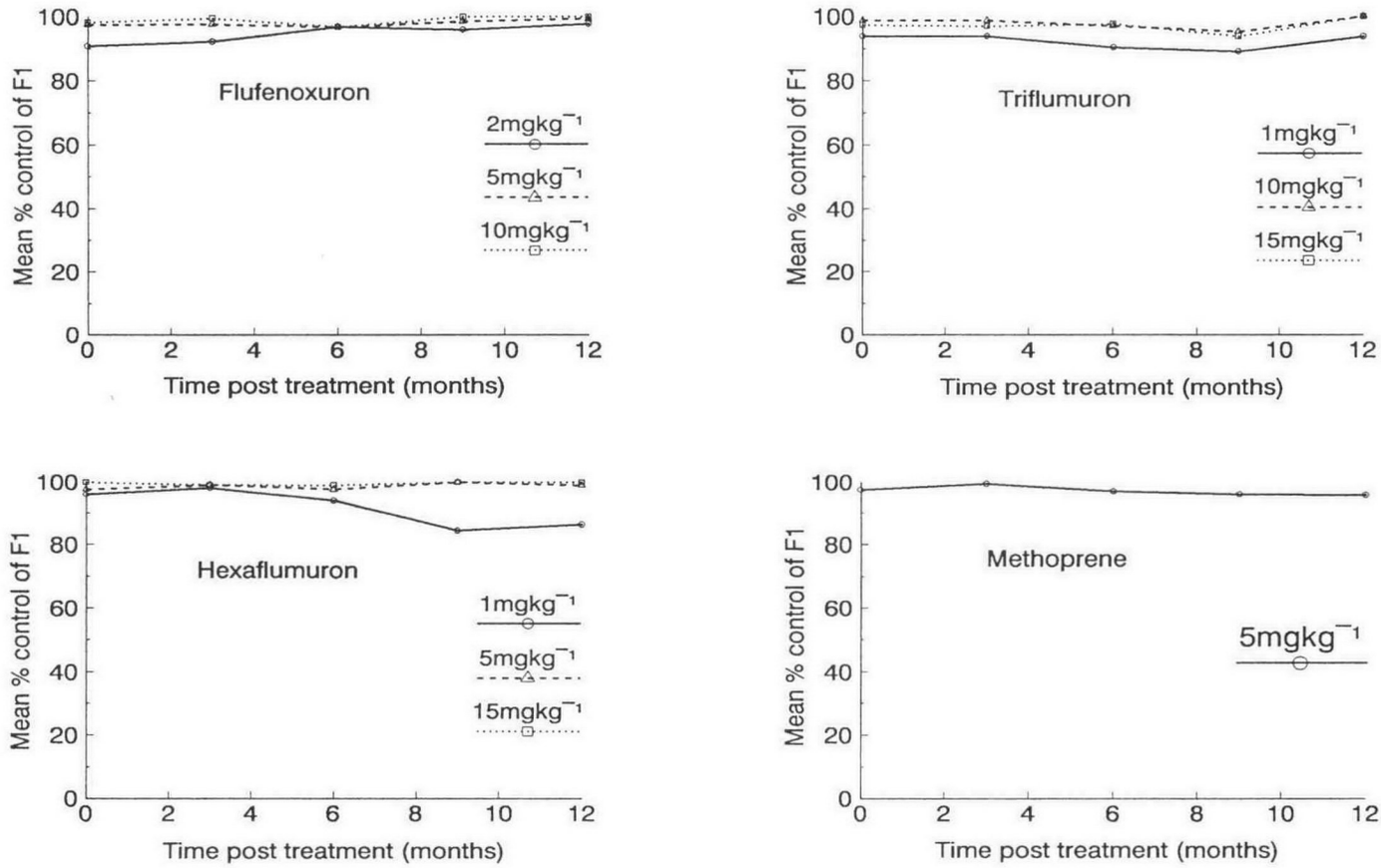


Fig. 2. Mean percentage control of F_1 progeny of *R. dominica* on treated maize.

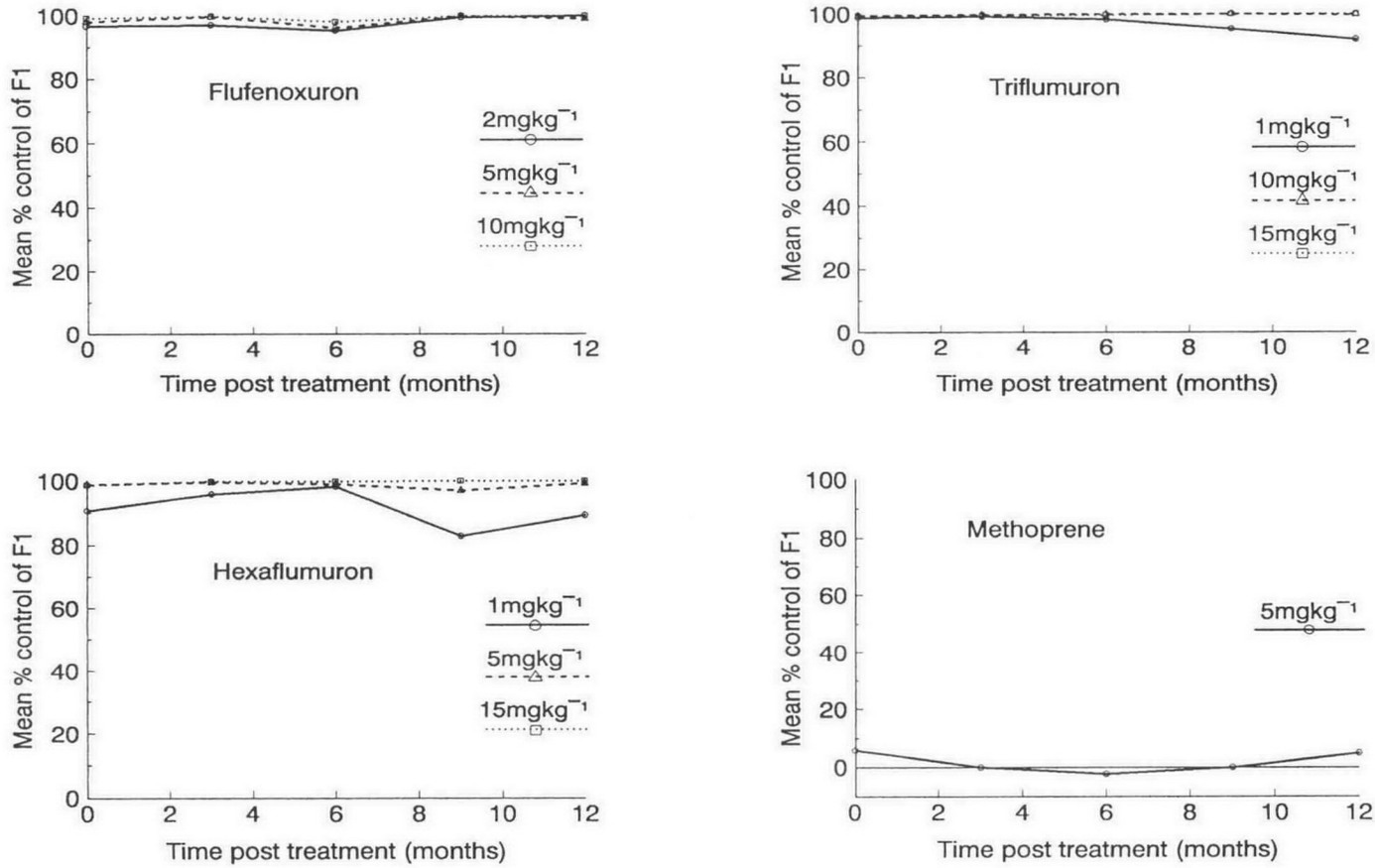


Fig. 3. Mean percentage control of F_1 progeny of *S. zeamais* on treated maize.

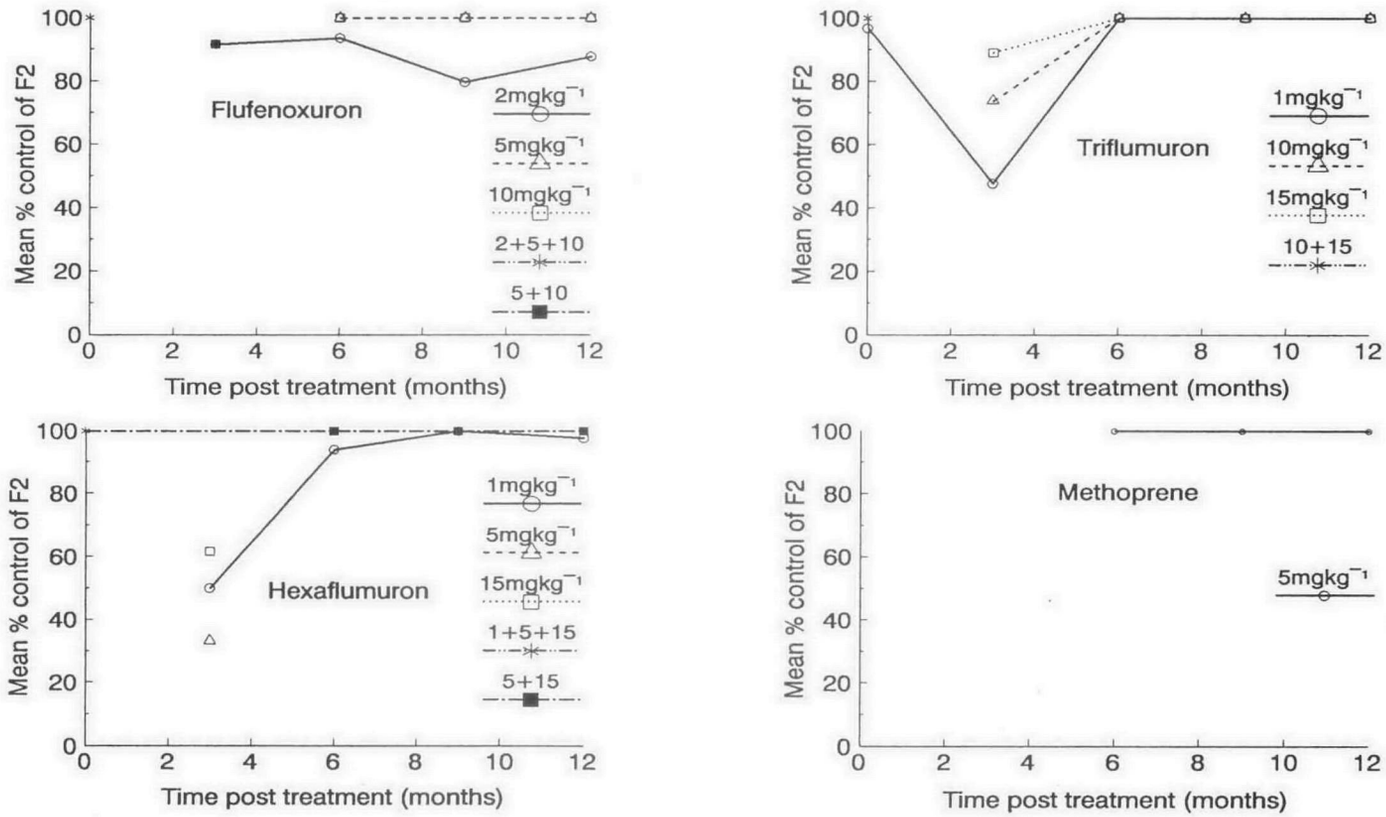
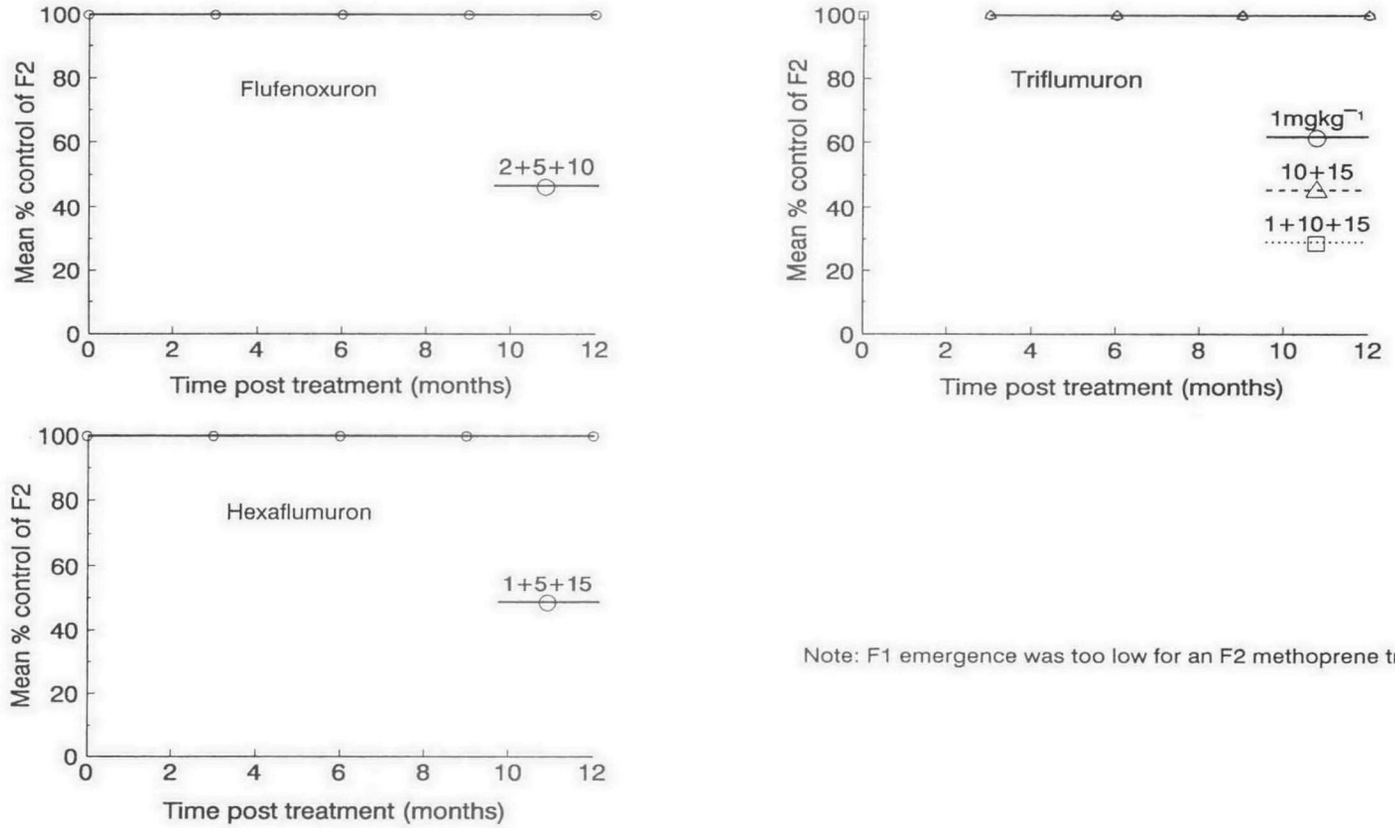


Fig. 4. Mean percentage control of F_2 progeny of *P. truncatus* on treated maize. Note that where F_1 emergence was low, some lines or points are described by legends in the form x + y + z. In order to maintain numbers in any one culture and thus ensure an acceptable sex ratio, the adults from cultures having x, y and z concentrations of IGR were collected together and put on maize which was treated at concentration x.



Note: F1 emergence was too low for an F2 methoprene trial.

Fig. 5. Mean percentage control of F_2 progeny of *R. dominica* on treated maize. Note that where F_1 emergence was low, some lines or points are described by legends in the form x + y + z. In order to maintain numbers in any one culture and thus ensure an acceptable sex ratio, the adults from cultures having x, y and z concentrations of IGR were collected together and put on maize which was treated at concentration x.

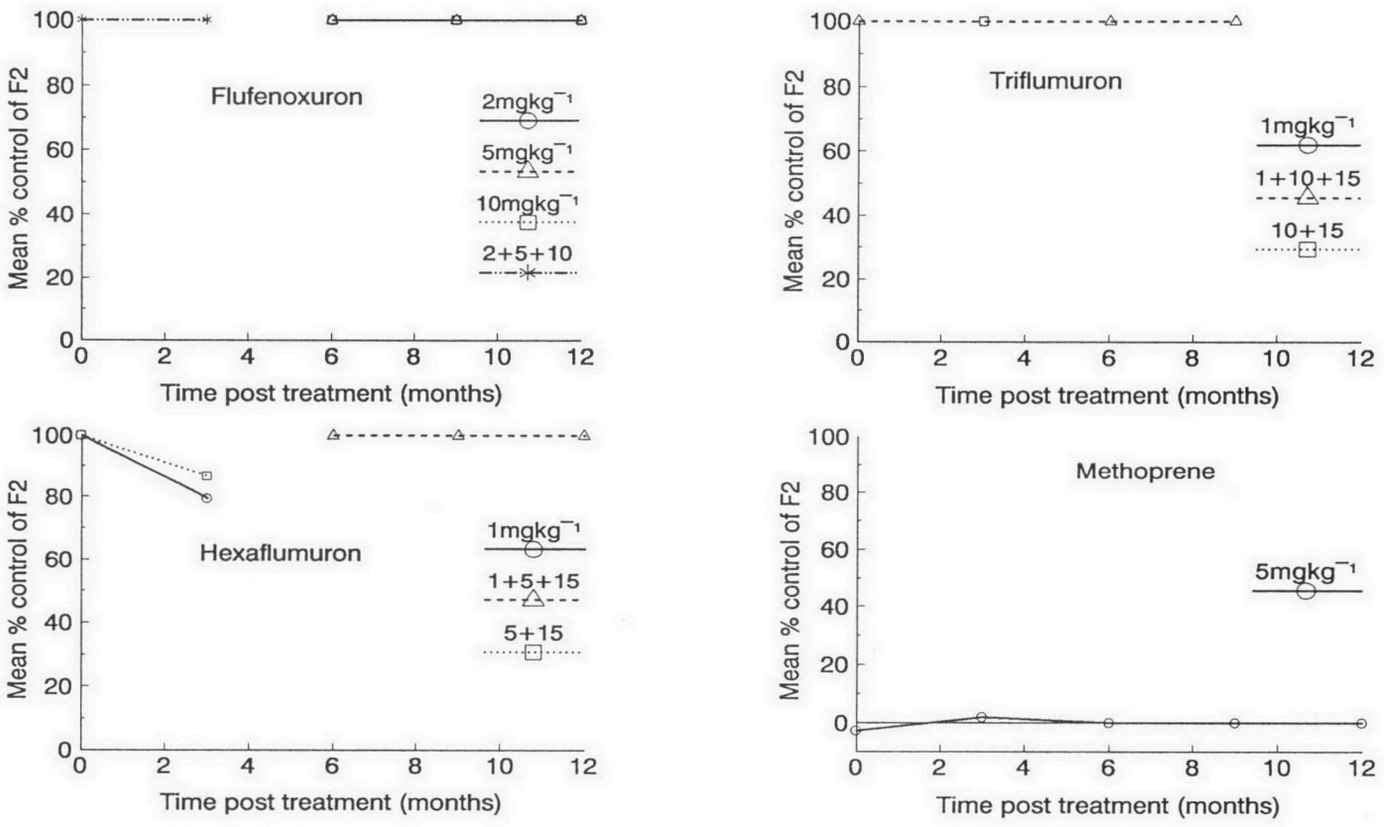


Fig. 6. Mean percentage control of F_2 progeny of *S. zeamais* on treated maize. Note that where F_1 emergence was low, some lines or points are described by legends in the form x + y + z. In order to maintain numbers in any one culture and thus ensure an acceptable sex ratio, the adults from cultures having x, y and z concentrations of IGR were collected together and put on maize which was treated at concentration x.

flufenoxuron at 5 mg/kg produced 93% control of F_1 progeny of *S. oryzae*, 8 months after treatment (Ammar, 1988). Hexaflumuron at 10 mg/kg applied to wheat produced 100% control of S. oryzae after 6 months, declining to 77% control at 12 months (Eisa and Ammar 1992).

Triflumuron at 1–10 mg/kg on wheat, barley and maize has been reported to provide a good level of control against *S. oryzae* and *R. dominica* for 12 months (Mian and Mulla, 1982). Other studies have shown that triflumuron on wheat, at 10 mg/kg produced 100% control of *S. oryzae* for 15 months (Eisa and Ammar 1992). In the present trial triflumuron applied to maize at 1–15 mg/kg has been found to be effective against *S. zeamais* and *R. dominica*, but less effective against *P. truncatus*. Methoprene is registered for the control of various insect pests of storage situations. Its low activity against *Sitophilus* species is well documented (Loschiavo 1976; Daglish and Samson 1991). In the present study, it was found that methoprene produced greater than 90% control of F_1 adult *P. truncatus* (except for 9 months). The residual efficacy of flufenoxuron, hexaflumuron and triflumuron at application rates of less than 10 mg/kg, reaffirm their suitability as potential grain protectants.

Conclusion

Four IGRs have been examined for their residual efficacy against three insect pests of stored products. Applications of 5 mg/kg of flufenoxuron, 5 mg/kg hexaflumuron or 10 mg/kg triflumuron have produced greater than 90% control of F_1 adult progeny of *P. truncatus*, *R. dominica* and *S. zeamais* whilst 5 mg/kg methoprene has been shown to be effective against *P. truncatus* for a 12-month storage period.

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