Effects of Five Insect Growth
Regulators on Progeny Production,
Productivity Index, Development,
and Adult Emergence of the Rice
Weevil, *Sitophilus oryzae* (L.)
(Coleoptera: Curculionidae)¹

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The Rice weevil, *Sitophilus oryzae* is an important pest of stored grains in many parts of the world. Insect growth regulators (IGRs) offer an alternative to the conventional insecticides whose use to control stored grain pests is handicapped by problems of residual toxicity and development of resistance in the pests (THOMAS and BHATNAGER-THOMAS, 1968). We have reported elsewhere (GUPTA and MKHIZE, 1983; MKHIZE and GUPTA, 1982) the effects of Hydroprene and R-20458 on the development and morphogenesis of the immature stages of the weevil and the follicular epithelium of the adult oocyte, and have discussed (MKHIZE and GUPTA, 1983) the importance of formulating IGRs with suitable surfactants to increase their effectiveness at lower dosages. The objective of the present paper is to report the effectiveness of 5 IGRs on the rice weevil in terms of their effects on adult progeny production, produc-

tivity index, development, and adult emergence.

The weevils used in this study were from cultures maintained in our laboratory and were obtained from the U.S. Grain Marketing Research Center, Manhattan, Kansas, and had no prior history of exposure to insecticides. The 5 IGRs used are: (6', 7'-epoxy-3'-ethyl-7'-methyl-undec-2'-enyl 6-ethyl-3-pyridyl ether (compound I); 6', 7'-epoxy-3'-ethyl-7'-methyl-dec-2'-enyl 6-ethyl-3-pyridyl ether (compound II); 6', 7'-epoxy-3, 7'-dimethyl-undec-2'-enyl 6-ethyl-3-pyridyl ether (compound III); 6', 7'-epoxy-3', 7'-dimethyl-dec-2'-enyl 6-ethyl-3-pyridyl ether (compound IV); 3', 7'-dimethyl-undec-2'-6'-dienyl 6-ethyl-3-pyridyl ether (compound V))

Stock solution of each compound was prepared in acetone. Acetone solutions were added to wheat to provide 10 ppm (v/v) concentrations of the IGRs. Five ml of each solution was applied to 250 g of wheat in a mason jar. Additional jars served as controls: one containing wheat treated with acetone, and the other containing only untreated wheat. Each treatment and controls were replicated 3 times, and left overnight to equilibrate. After equilibration, 100 unsexed adult rice weevils were randomly placed in each jar, and all the jars placed in an incubator maintained at $29 \pm 1^\circ\text{C}$ and 63–64% RH for 3 weeks for oviposition. After 3 weeks, the jars were reexamined for F_1 progeny production. Productivity index (=No. of F_1 progeny in treatment over No. of F_1 progeny in control $\times 100$) and percentage reduction in adult emergence were calculated.

Topical applications of 2.5 ppm of each compound (0.3 $\mu\text{l}/\text{insect}$) were made on batches of 50

Table 1. Effects of IGRs (wheat treated with 10 ppm (v/v) on progeny production, productivity index, and adult emergence of *S. oryzae* 6 weeks after treatment

IGRs	Mean no. of F_1 progeny	Productivity index	Percent reduction in adult emergence
Control	640	0	0
Control+Acetone	631	98.6	1.4
Compound I	53	8.3	91.7
Compound II	6	0.9	99.1
Compound III	93	14.5	85.5
Compound IV	50	7.8	92.2
Compound V	75	11.7	88.3

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Table 2. Effects of topical applications of IGRs (0.3 μ l/insect) on the pupae of *S. oryzae*

IGRs	No. of dead pupae	No. of pupal-adult intermediates	No. of emerged adults	Percent survival	Percent mortality	Corrected percent mortality ^a
Control	6	0	42	88	12	
Compound I	6	34	10	20	80	75.0 a
Compound II	7	28	15	30	70	65.9 b
Compound III	14	30	6	12	88	86.4 a
Compound IV	4	33	13	26	74	70.5 b
Compound V	7	34	9	18	82	79.5 a

^a Abbott's formula.Mortality values not followed by the same letter are significantly different ($p < 0.05$; by Chi-square analysis).Table 3. Effects of topical applications of IGRs (0.3 μ l/insect) on the 4th instars of the Rice weevil, *S. oryzae*

IRGs	No. of dead larvae	No. of larval-pupal int.	No. of dead pupae	No. of pupal-adult int.	No. of emerged adults	Percent sur.	Percent mortal.	Corrected percent mortal. ^a
Control	5	0	0	0	45	90	10	
Compound I	6	18	2	6	18	36	64	60.0 a
Compound II	10	10	6	5	19	38	62	57.8 b
Compound III	15	14	0	5	15	30	70	66.7 a
Compound IV	12	10	0	11	17	34	66	62.2 a
Compound V	9	15	1	3	22	44	56	51.1 b

^a Abbott's formula.

int: intermediate; sur.: survival; mortal.: mortality.

Mortality values not followed by the same letter are significantly different ($p < 0.05$; by Chi-square analysis).

4th instar larvae and pupae because these stages were found to be the most susceptible to IGR treatment. Test insects and controls were placed singly in a vial containing untreated medium that consisted of wheat flour, corn starch and yeast in the ratio 10: 3: 1 by weight. The vials were placed in the incubator until adults emerged.

Insects from wheat and topical treatments were examined for external morphological abnormalities and any effects on molting and metamorphosis. Mortality in the treatments was corrected for mortality in the control groups by Abbott's formula. Data were subjected to Chi-square analyses.

Data in Table 1 show mean F_1 progeny, productivity index and % reduction in adult emergence 6 weeks after the treatment. The effectiveness of the IGRs was in the order II>IV>I>V>III; these

differences in effectiveness were very significant. It is apparent that compound II is most effective in treated wheat, as indicated by the lowest F_1 progeny and productivity index and greatest percent reduction in adult emergence (i.e. increased mortality). Compound III, however, proved to be most effective of the 5 compounds in topical treatment (Table 3), as indicated by highest mortality. The effect was greater on pupae (Table 2) than on the 4th instar larvae (Table 3), indicating that perhaps the pupae were more susceptible than the 5th instar larvae. It was possible to obtain reliable data for younger larvae because of the high mortality both in treatments and the controls due to undertermined causes.

All IGRs used produced similar morphological abnormalities, ecdysial failures, and metamorphic

defects. There were no supernumerary forms in any of the treatments. External morphological abnormalities included crimped hind wings in the adults. This was probably not due to abnormal quantities of microtubules as reported for the aphid (WHITE and GREGORY, 1972), since wing venation was normal. However, the ability of the wings to expand and flatten was reduced, as reported for the German cockroach, *Blattella germanica* (DAS and GUPTA, 1974). Some of the apparently normal adult weevils had partially pigmented elytra. Some IGRs, e.g., R-20458 (6, 7-epoxygeranyl 4-ethylphenyl ether) and Ro 20-3600 (6, 7-epoxygeranyl 3, 4-methylenedioxyphenyl ether) are known to cause excessive melanization in the German cockroach (DAS and GUPTA, 1974). Ro 20-3600, however, prevented melanization in the tobacco hornworm, *Manduca sexta* (BAGLEY and BAUERFEIND, 1972).

There were ecdysial failures such as the presence of larval skin on an otherwise normal pupa. In some cases, pupal exuvia were found sticking to the tarsi, central part of the abdomen or tip of the abdomen of adult weevils, as reported elsewhere (GUPTA and MKHIZE, 1983). IGRs that mimic JH activity when applied to the last larval or pupal stage interfere with normal molting and metamorphosis (SLÁMA et al., 1974). The ecdysial failures described above were mild and were not observed in young larvae. Therefore, as suggested by SLÁMA et al. (1974), they may be considered as special side effects due to disturbed biometric proportions in body shape. Another effect of high titer of exogenous JH at metamorphosis is the inhibition of normal development from one stage to another; it

leads to repetition of larval or pupal structures, resulting in the production of larval-pupal and pupal-adult intermediates (SLÁMA et al., 1974). In our study, larval-adult intermediates were also produced, possibly resulting from accelerated development, thus shortening the pupal stage.

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