Activity of Insect Growth Regulators, Hydroprene and Methoprene, on Wheat and Corn Against Several Stored-Grain Insects[1]

HARRISON E. MCGREGOR and KARL J. KRAMER[2]

ABSTRACT

Two insect growth regulators (IGR), hydroprene and methoprene, when applied to wheat and corn kernels at concentrations ranging from 2 to 10 ppm, prevented the metamorphosis of the Indian meal moth, *Plodia interpunctella* (Hübner), and effectively reduced the F_1 populations of the lesser grain borer, *Rhyzopertha dominica* (F.), the confused flour beetle, *Tribolium confusum* Jacquelin duVal, and the sawtoothed grain beetle, *Oryzaephilus surinamensis* (L.). However, they were not as effective against the rice weevil, *Sitophilus oryzae* (L.), since substantial numbers of progeny developed in wheat kernels treated at a rate of 10 ppm with either of the compounds.

Strong and Diekman (1973) screened 15 synthetic compounds for insect growth activity against 12 pests of stored products in various food substrates and found that hydroprene and methoprene were active in all species tested. However, these workers used only whole grain with 3 species, the lesser grain borer, *Rhyzopertha dominica* (F.), the granary weevil, *Sitophilus granarius* (L.), and the rice weevil, *S. oryzae* (L.). We corroborated and extended their study by evaluating these two insect growth regulators as candidate protectants of wheat and corn against the lesser grain borer, the rice weevil, the confused flour beetle, *Tribolium confusum* Jacquelin duVal, the sawtoothed grain beetle, *Oryzaephilus surinamensis* (L.), and the Indian meal moth, *Plodia interpunctella* (Hübner).

MATERIALS AND METHODS.—The 5 test insects were obtained from the U.S. Grain Marketing Research Center Laboratory cultures and had no prior history of exposure to insecticides. The lesser grain borer and the rice weevil represented internal grain feeders; the confused flour beetle, the sawtoothed grain beetle, and the Indian meal moth represented external grain feeders.

The 'Chanute' variety of wheat and the 'Pioneer 373' variety of corn used in the tests were obtained from commercial sources. The kernels were cleaned and tempered to a moisture of 12.5±0.5%, as determined by a Motomco® moisture meter.

Methoprene and hydroprene (Henrick et al. 1973) were obtained from Zeocon Corp., Palo Alto, Calif., in both technical grade (65% pure) and EC and were stored at 4°C until used. Stock solutions of technical grade material in acetone or EC in water were prepared to provide rates of 5 and 10 or 2 and 4 ppm (wt/wt), respectively. The IGR's were applied to the kernels by uniformly pipetting 5 ml of the appropriate stock solution onto the inside surface of a rotating jar containing 1000 g of wheat or corn. Then the jar was placed for 20 min on a mechanical tumbler operating at 40 rpm. The preparation was allowed to equilibrate for at least 24 h. We also tested an equal weight mixture of the 2 compounds because some insects have shown tolerance to either methoprene or hydroprene (e.g., the rice weevil).

The treated grain was divided into 500-g lots, each placed in a quart jar. Two percent grain dockage (untreated or treated) was added to the jars used to test the external grain feeders so as to provide a more suitable food substrate for newly emerged larvae. For the tests with Coleoptera, 50 unsexed adults were collected at random and placed in each jar. For the tests with the Indian meal moth, 10 larvae (2nd or 3rd instar) were placed in each jar. All insects were exposed to the grain at 27±2°C and 60±5% RH for 3 wk. Then the grain was screened, adult insects were removed, and any surviving adults were placed in untreated grain and held an additional 3 wk. In most tests, the progeny was counted 6 wk after the adults were removed, i.e., after more than adequate time had elapsed for the F_1 generation to mature in untreated grain. In some cases, the grain was examined after 6 months. All progeny was checked for any external morphological abnormalities.

RESULTS.—Rates of 2 and 4 ppm of hydroprene, methoprene or their equal weight mixture on wheat kernels affected a 99% or greater reduction in adult F_1 progeny of the lesser grain borer (Table 1). Also, the F_1 population emerging from treated corn kernels was reduced. However, corn was not as suitable a food substrate as wheat for the grain borer. Only 2% as many *R. dominica* adults emerged in the control corn. No larval-pupal or pupal-adult intermediates were found to have emerged from any of the kernels. As was the case for all other beetles tested, the IGR's were not toxic to the parent adults, and eggs deposited on untreated grain by beetles that had been exposed to treated grain developed normally.

Rice weevil progeny was not affected substantially by either IGR when wheat was treated with 5 and 10 ppm (Table 1). The application of 10 ppm of hy-

[1] Mention of a pesticide or a proprietary product does not constitute a recommendation or an endorsement by the USDA. Received for publication Apr. 24, 1975.

[2] U.S. Grain Marketing Res. Center, Agric. Res. Serv., USDA, Manhattan, KS 66502.

Table 1.—Effect of hydroprene and methoprene applied to wheat and corn on maturation of F_1 populations of 4 species of grain beetles.

Compound	Concn (ppm)	Wheat: No. adults developed	Wheat: % reduction	Corn: No. adults developed	Corn: % reduction
		Lesser grain borer			
Hydroprene	0	4112		267	
	2	60	99	21	92
	4	12	>99	15	94
Methoprene	0	4676		66	
	2	7	>99	10	87
	4	4	>99	0	100
1:1 mixture	0	3213		104	
	2	8	>99	10	91
	4	1	>99	7	93
		Rice weevil			
Hydroprene	0	7181			
	5	5932	17		
	10	4635	35		
Methoprene	0	4300			
	5	4850	(13)[a]		
	10	3760	13		
1:1 mixture	0	4300			
	10	3600	16		
		Confused flour beetle			
Hydroprene	0	1605		1475	
	2	122	92	0	100
	4	0	100	5	>99
	0	9446			
	5	0	0		
	10	24	>99		
Methoprene	0	1213		1240	
	2	0	100	2	>99
	4	0	100	1	>99
	0	245			
	5	0	100		
	10	0	100		
1:1 mixture	0	477		1196	
	2	88	84	0	100
	4	1	>99	0	100
	0	815			
	5	0	100		
	10	0	100		
		Sawtoothed grain beetle			
Hydroprene	0	3783		3479	
	2	425	89	75	98
	4	2	>99	19	>99
Methoprene	0	3761		2442	
	2	0	100	0	100
	4	0	100	0	100
1:1 mixture	0	2564		2361	
	2	1	>99	0	100
	4	3	>99	0	100

[a] Parenthesis denotes % increase.

droprene did reduce the F_1 population to 65% of that of the control, but that rate of methoprene or the mixture caused reductions of only 13 and 16%, respectively. We did not test corn as a food substrate because the compounds had such low activities on wheat.

The development of adult *T. confusum* was effectively disrupted by treatment of wheat and corn with 2–5 ppm methoprene, hydroprene or the mixture (Table 1). When adult insects did appear, they were always malformed except in the case where corn was treated with hydroprene.

No F_1 sawtoothed grain beetles were found when either wheat or corn was treated with 2 ppm methoprene (Table 1). Also, 4 ppm hydroprene caused a greater than 99% reduction. Numerous larval-pupal intermediates were obtained in these tests.

Treatment with as little as 2 ppm of either IGR compound prevented the development of the immature larvae of the Indian meal moth on either wheat or corn. The number of adults that emerged in the controls ranged from 185–496. In treated grain, extra large or supernumerary larvae were produced that died, apparently through failure of some vital function. Also, webbing activity of larvae reared on treated grain decreased significantly.

Discussion.—Thomas and Bhatnagar-Thomas (1968) and Bhatnagar-Thomas (1973) first reported on the use of an IGR (JH analogue) as an insecticide for pests of stored grain. They found that methyl 3,7,11-trimethyl-7,11-dichloro-2-dodecenoate prevented development of the 2nd generations of *T. castaneum* (Herbst), *Stegobium paniceum* (L.), *Bruchus chinensis* L., and *S. granarius* on whole wheat, and *R. dominica* on sorghum. Metwally et al. (1972) found hydroprene highly active in inhibiting the morphogenesis and reproduction of a dermestid *Trogoderma granarium* Everts. By application of JH (methyl 10, 11-epoxy-7-ethyl-3,11-dimethyl-2,6-tridecadienoate) or its geometrical isomers, Schwieter-Peyer (1973), Amos et al. (1974) and Silhacek and Oberlander (1975) prevented metamorphosis of the granary weevil, red flour beetle, and the Indian meal moth, respectively. Hoppe (1974) used 6,7-epoxy-3,7-dimethyl-1-[1-3,4-(methylenedioxy) phenoxy]-2-nonene on wheat to prevent the occurrence of a 2nd generation of the Mediterranean flour moth, *Anagasta kuehniella* (Zeller). As noted earlier, Strong and Diekman (1973) found that methoprene and hydroprene were the most active compounds in preventing the development of successive generations of 12 species of stored-product insects. Similarly, we found that hydroprene and methoprene applied to grain kernels at concentrations ranging from 2 to 5 ppm effectively reduced the development of successive generations of the lesser grain borer, the confused flour beetle, and the sawtoothed grain beetle. These compounds also prevented Indian meal moth larvae from attaining maturity. They were not toxic to the adult stage of any species tested and had no effect on the reproductivity of the parent beetles or on the viability of the eggs deposited. Both the technical and emulsifiable formulations gave comparable results.

Our results are in good agreement with those of Strong and Diekman (1973) except that hydroprene was less active (ca. 3 times) against the rice weevil and more active toward the sawtoothed grain beetle in our tests. However, these disparities are small and

not unreasonable because the experimental conditions were not identical. Different culture media were used for several of the insects, and Strong and Diekman (1973) placed their insects on treated media immediately, while we waited until 24 h after treatment. In general, we found that the 2 IGR's showed similar activity against the confused flour beetle, the Indian meal moth, and the lesser grain borer and that methoprene was more active against the sawtoothed grain beetle and hydroprene against the rice weevil.

Hydroprene and methoprene show promise as commodity protectants since they could prevent the development of large populations of insects in stored wheat and corn if mixed with whole grain under bulk storage, particularly as part of an integrated pest control program. The doses we used on whole grain were nearly sufficient to completely eliminate the F_1 adults of all species tested except the rice weevil. The poor control of the F_1 generation of the rice weevil which develops inside grain kernels where little or no IGR may be present could be the result of *Sitophilus* species being less susceptible to these compounds. Indeed, evidence on other curculionid beetles suggests that this family is relatively insensitive to IGR's of the JH type (Staal 1975). If these compounds are to be generally applicable, i.e., so that they control internal grain feeders such as the rice weevil, either more active or better penetrating formulations must be developed.

ACKNOWLEDGMENT.—We thank Dr. John D. Diekman, Zoecon Corp., for a critical review of the manuscript, Leon Hendricks USGMRC, for able technical assistance, and Zoecon Corp., Palo Alto, Calif., for the insect growth regulators.

REFERENCES CITED

Amos, T. G., P. Williams, P. B. Du Guesclin, and M. Schwarz. 1974. Compounds related to juvenile hormone, activity of selected terpenoids in *Tribolium castaneum* and *T. confusum*. J. Econ. Entomol. 64: 474–6.

Bhatnagar-Thomas, P. L. 1973. Control of insect pests of stored grains using a juvenile hormone analogue. Ibid., 66: 277–8.

Henrick, C. A., G. B. Staal, and J. B. Siddall. 1973. Alkyl 3,7,11-trimethyl-2,4-dodecadienoates, a new class of potent insect growth regulators with juvenile hormone activity. J. Agric. Food Chem. 21: 354–9.

Hoppe, T. 1974. Effect of a juvenile hormone analogue on Mediterranean flour moth in stored grains. J. Econ. Entomol. 67: 789.

Metwally, M. M., F. Sehnal, and V. Landa. 1972. Reduction of fecundity and control of the Khapra beetle by juvenile hormone mimics. Ibid., 65: 1603–5.

Schwieter-Peyer, B. 1973. Comparison of the effect of the geometrical isomers of juvenile hormone on *Blatella germanica, Dysdercus angulatus* and *Sitophilus granarius*. Insect Biochem. 3: 275–82.

Silhacek, D. L., and H. Oberlander. 1975. Time-dosage studies of juvenile hormone action on the development of *Plodia interpunctella* (Hübner). J. Insect Physiol. 21: 153–61.

Staal, G. B. 1975. Insect growth regulators with juvenile hormone activity. Annu. Rev. Entomol. 20: 417–60.

Strong, R. G., and J. Diekman. 1973. Comparative effectiveness of fifteen insect growth regulators against several pests of stored products. J. Econ. Entomol. 66: 1167–73.

Thomas, P. J., and P. L. Bhatnagar-Thomas. 1968. Use of a juvenile hormone analogue as insecticide for pests of stored grain. Nature (Lond.) 219: 949.