EFFECTS OF VARIOUS MITICIDES UPON AN ECTOPARASITIC MITE (PYEMOTES SP.) IN RICE WEEVIL AND ANGOUMOIS GRAIN MOTH CULTURES

by 3235 N.C.

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B. S., Kansas State University, 1966

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Entomology

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1970

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INTRODUCTION

The purpose of this study was to find a simple, effective means of controlling *Pyemotes* sp. infestations in stored-product insect cultures.

The mites mature within the enlarged "brood pouch" of the gravid female and may mate immediately after birth. The young females then search for an insect larva upon which to feed.

Severe infestations of these ectoparasitic mites occurred several times in the Kansas State University stored-product insect rearing rooms. Angoumois grain moths and rice weevils reared in quart jars containing wheat were usually the most severely attacked. The immature stages of the insects are attacked by the mites which cause paralysis and eventually death. Pupae and adult insects are less frequently attacked. Effective control is difficult due to the mite's microscopic size (Plate I), their ability to attack insect larvae within kernels of grain (Plate II, Fig 1), and their capability of developing under the elytra of insects (Plate II, Fig 2). Control of these mites is desirable in cultures of insects used for research purposes.

When a severe infestation of mites occurred in a rearing room, the room was cleared of all cultures and those infested were destroyed by freezing. The rearing room was then cleaned, washed, and treated with a miticide. New mite-free cultures were started in clean culture wheat by using mite-free eggs of some species, and in other cases using extreme care when transferring stock insects from one jar to another. In the latter there was no assurance that unnoticed mites attached to the adults were not transferred to the clean media. At least 1 to 1½ months were needed to restore insect cultures to normal production and research was interrupted for that time. In addition to the time lost, partially completed research projects sometimes had to be terminated.

An effective means of mite disinfestation is needed when preventive measures fail. The method must necessarily permit at least some of the insects to survive to maintain the culture of the species.

This study was an attempt to control the mites by using miticide dry formulations directly in the wheat cultures of Angoumois grain moths and rice weevils to eliminate the mites while allowing the insects to survive and reproduce.

REVIEW OF LITERATURE

Most of the literature on mites of the family Pyemotidae is concerned with *Pyemotes ventricosus*. The species was first described as *Herterpus ventricosus* by Newport in 1850 (Baker, 1952). The generic name was changed to *Pediculoides* by Targioni-Tozzetti in 1878. Even though the generic and family names were changed to *Pyemotes* and Pyemotidae, respectively, by Oudemans in 1937, much of the literature as late as the 1950's refers to the mite as *Pediculoides*.

Although there is a large body of literature on the life cycle of *Pyemotes*, their parasitic activity, and their behavior as a pest to man, little was found in the literature concerning their control in stored-grain insect cultures. The literature is reviewed under three major headings: effects of mites on insects, medical importance, and control.

Effects of Mites on Insects. Weiser and Slama (1964) studied the effects of the toxin of *Pyemotes zwolferi* on the greater wax moth, *Galleria mellonella* (L.). They reported that the mites first fastened legs I to the curved portion of the intersegmental membrane (also observed in the present

EXPLANATION OF PLATE I

Fig. 1. Male *Pyemotes* mites .15 mm long and .06 mm wide.

Fig. 2. Newly emerged female *Pyemotes* mite .30 mm long and .07 mm wide.

Fig. 3. Gravid female *Pyemotes* mite with abdomen diam about .67 mm.

PLATE I

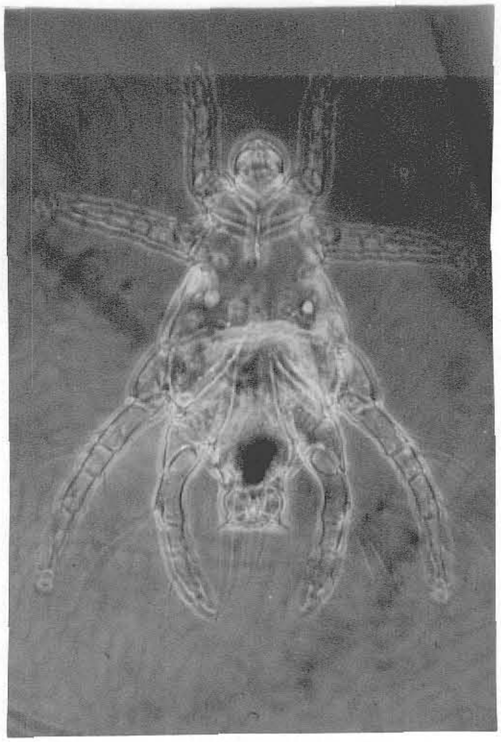
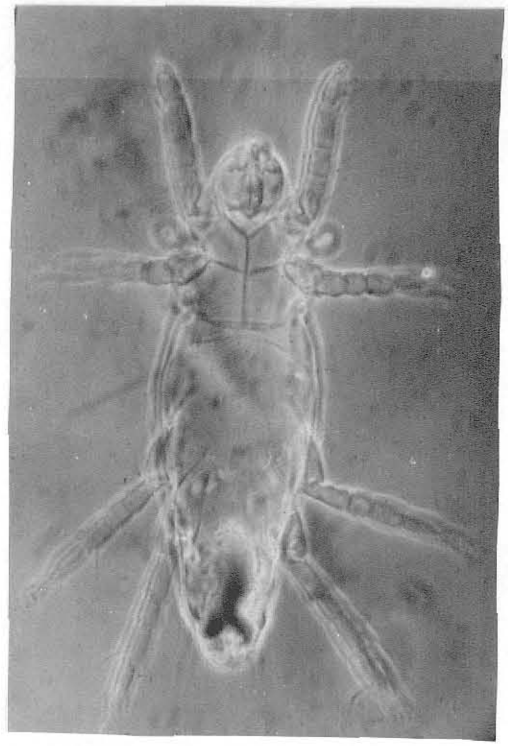


Fig. 1



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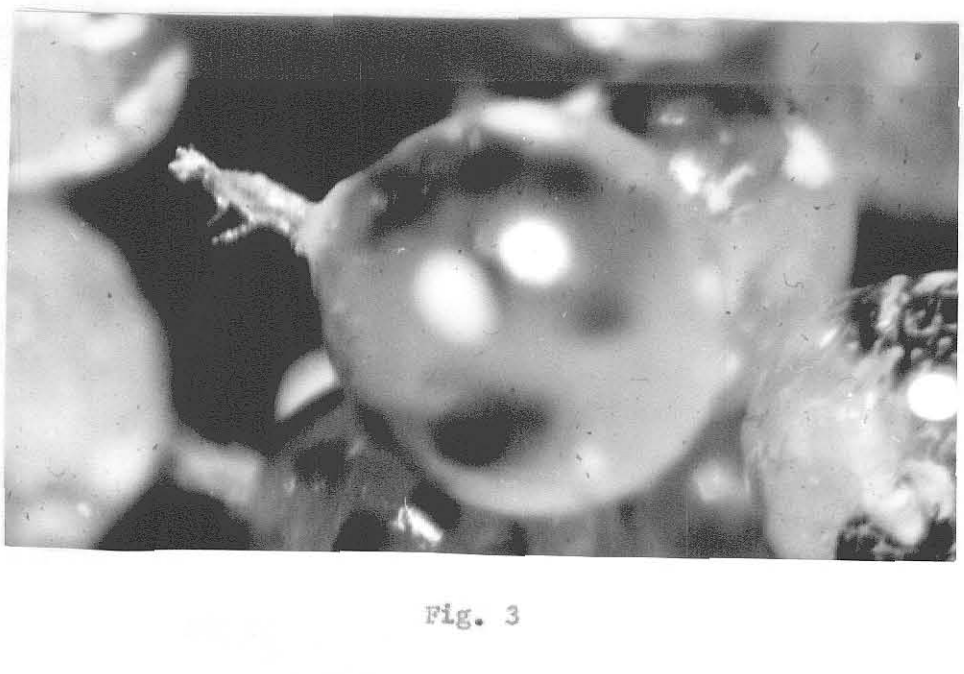


Fig. 3

EXPLANATION OF PLATE II

Fig. 1. X-ray radiograph showing gravid *Pyemotes* females on an Angoumois grain moth larva within a wheat kernel.

Fig. 2. X-ray radiograph showing a gravid female *Pyemotes* attached under the elytra of a rice weevil.

PLATE II

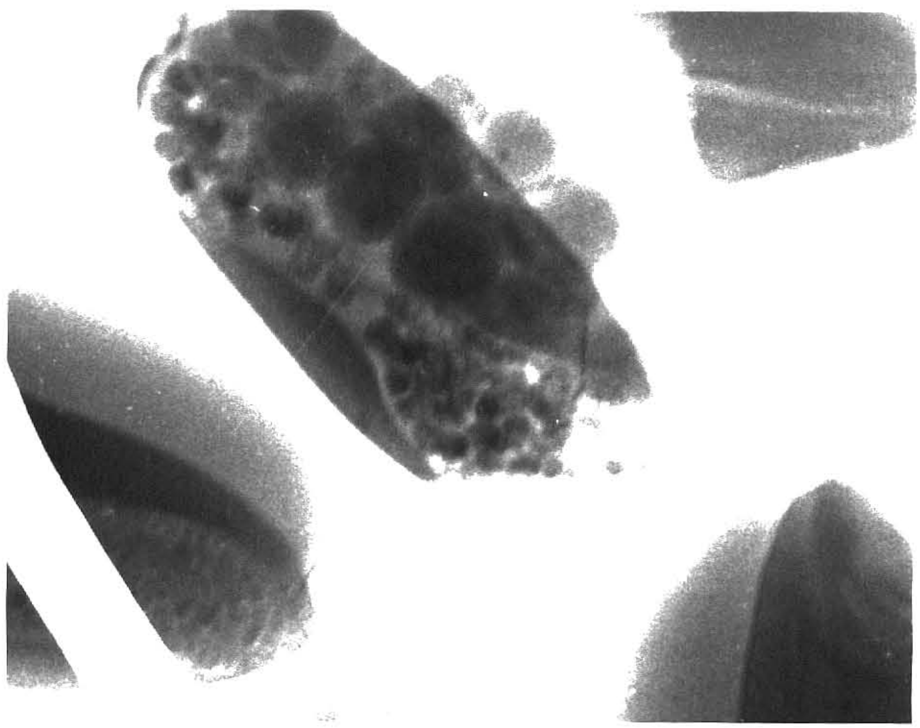


Fig. 1

Fig. 2

study). The chelicerae were then pressed against the integument. Legs IV were used to increase leverage which helped force the mouthparts into a small hole formed by the chelicerae. The *Galleria* larva reacted to the piercing with frantic movements which decimated and squashed some mites (Weiser, 1963). Toxin is then injected into the host by a small pair of glands located in the base of the pedipalps. The initial violent of highly agitated reaction by the larvae to the toxin slowly diminished. This period varied from a few minutes to several hours depending upon the number of bites the larva incurred. Weisner and Slama (1964) reported a definite decrease in oxygen consumption by the paralyzed larvae. It was concluded that the drop in respiration resulted from the cessation of motor activity. As the larvae continued to live for two to three days while paralyzed, they believed death was caused by starvation rather than toxication.

Medical Importance. *Pyemotes* spp. have attacked man when the mite population was high. This is most commonly reported in and around grain elevators and at harvest time in the cereal growing regions of the world. The mite populations develop on the insects in the grain of straw. In the search for new hosts, they attack humans causing "grain itch" and the mite has been referred to as the "grain itch mite." The condition resulting from attacks on man has also been called "hay itch" and "harvest itch" in early reports. At the site of the bite a local lesion forms one-fourth to one-half inch in diameter. Maximum development of the wheal is reached in 24 hr, subsiding gradually within the next 48 to 72 hr (Webster, 1910; Booth and Jones, 1952). Typical symptoms caused by severe attacks are: many intensely pruritic eruptions surmounted by a vesicle or pustule, nausea, vomiting, high fever, and back and joint aches. Since man is not an acceptable host, the mites cease feeding and die.

According to Booth and Jones (1952), P. ventricosus was abundant in the midwest and eastern U.S. from 1901 to 1910 with a number of large epidemics of itch among harvesters in Ohio and Indiana during 1908, 1909, and 1910. In 1909 Schamberg and Goldberger in Philadelphia independently demonstrated that Pyemotes was the cause.

Webster (1910) reported a severe outbreak in Philadelphia in 1909. Suitable conditions for a P. ventricosus outbreak were provided by a high "grain moth" population before harvest and the rapid decline of the moth population after harvest. People were attacked in their sleep by mites leaving mite-infested straw which had been used as bedding. One hundred cases were traced directly to the "grain itch mite," P. ventricosus. Over 1,000 wheals were counted on the body of one women.

Larson (1925) reported a dermatitis caused by Pediculoides ventricosus among workers who handled infested cowpeas in his laboratory. Several workers who handled the cowpeas were severely bitten about the hands and arms. A person with a fair complexion had fever symptoms, a burning sensation of the skin, and cold chills persisted for about 24 hr. Individuals with darker complexions did not exhibit symptoms of this severity.

According to Booth and Jones (1952), mites were uncommon after 1910 but became a serious problem in 1950 and 1951. Harvesters were chiefly affected by a widespread epidemic of P. ventricosus infestation of farm workers which occurred in central and southern Indiana in 1950 and 1951. Although epidemics predominantly occurred at harvest time, some severe infestations occurred throughout the entire summer of 1950 and 1951.

The use of mite-infested straw in the livestock pavilions at the

Indiana State Fair resulted in 260 infested persons being treated at the Fair's Red Cross dispensary in 1950 and 382 persons being treated in 1951. In addition 1,100 4H'ers were treated outside the Red Cross dispensary during the 1950 and 1951 Indiana State Fair. Most patients had 200 to 300 bites per individual.

Control of Mites. No published information was found concerning the miticide control of Pyemotes spp. in stored-grain insect cultures. However, when questionnaires were sent to stored-grain insect research laboratories in the United States, Canada, England, and Scotland, replies showed great emphasis on prevention of mites in general in the rearing rooms. Various barriers of mineral oil and miticides were used, as well as sanitation.

Seal and Eden (1956) sprayed crickets with acaricides to control Tyrophagus breviceps (Banks) mites in cricket cultures being raised for fish bait. Wettable powders were sprayed with a small portable electric paint sprayer directly on the crickets until they were thoroughly wet. The crickets exhibited no toxic effects when sprayed with various dosages of Aramite, DMC, Ovotran, and Kelthane.

Gay and Graves (1942) found Pediculoides ventricosus troublesome in Sitophilus spp. cultures kept in well-ventilated jars for 8 wk. A 2% solution of dinitro-ortho-cyclohexylphenol in Shell C. oil G. 194 applied to cloth bands on the jars or wiped over the jar and lid eradicated the mites by preventing spread between jars. Partially effective were dusting the weevils with sulfur in wheat, B-napthol banded on the jars, and methyl salicylate put on paper in the jars and sprayed over the room.

Strong, et al (1959) studied the control of Typhlodromus and Acaropsis mites using miticides in granary weevil and rice weevil cultures. To obtain mite-free cultures they used diligent sterilization of grain for culture media at -10° F for 7 days and the use of parent weevils from mite-free cultures. In testing Typhlodromus mite control measures, sifted flour and miticide were put in glass vials to a controlled depth. After 14 days, the depth of the mite penetration was read and the information used for comparison. Effects of miticide on rice weevils and granary weevils were also determined by spraying the inside of a petri dish with 1.0% miticide. At 200 ppm Kelthane, the mean percentage mortality was 43% for rice weevils and 18% for granary weevils. At 500 ppm Kelthane, the mean percentage mortality was 64% for rice weevils and 48% for granary weevils. However, only Kelthane at 500 ppm gave complete eradication of the mites with the other miticides tested giving little or no control even at 500 ppm.

MATERIALS AND GENERAL METHODS

Insect Rearing. The Angoumois grain moths, Sitotroga cerealella (Oliv.), and rice weevils, Sitophilus oryzae (L.), were reared at 27 ±1° C and 70% ±3% RH in quart jars containing 13% moisture hard red winter wheat. The Angoumois grain moths were from the laboratory culture at Kansas State University. The original stock was collected in Anderson County, Kansas in 1960. The stock of rice weevils was a strain obtained from Georgia in 1961.

Greater wax moth larvae (Galleria mellonella L.) used as hosts to maintain the mite cultures were obtained from Robert Stryker's culture at Missouri University in 1967. These moths were reared in gallon jars on beeswax containing a small amount of honey. New cultures were started from eggs laid between folds of waxed paper by moths in established cultures. Last instars were used to maintain the mite culture.

Mite Rearing. The mites used were from cultures started from mites found in infested Angoumois grain moth cultures at Kansas State University. Female mites were sent to Dr. Earle A. Cross at Northwestern State College of Louisiana, Natchitoches, Louisiana, who has studied the taxonomy of Pyemotes mites. He keyed them to Pyemotes herfsi. However, both males and females sent to Dr. Cross from Missouri were believed to be a similar if not identical species to the mites at Kansas State. Females from Missouri also keyed to Pyemotes herfsi, but the males keyed to Pyemotes anobii. Cross sent the Missouri mites to Dr. Herbert Krczal in Germany who has done extensive work with the taxonomy of these mites. Krczal believed the Missouri mites to be a new species close to P. anobii. More mites including males were sent from Kansas for further identification, but the results aren't available at the time of this writing.

The mites were reared in staining dishes 9 cm in diam and 4 cm deep containing a 1.3 cm layer of plaster of Paris in the bottom which provided a suitable surface for the free moving mites. A 1.3 cm barrier of vaseline was put inside near the top of each staining dish to prevent escape of mites. A paper souffle cup (2.5 cm diam X 1.3 cm deep) with small holes punched in the bottom and containing a mite-infested wax moth larva was placed in the center of each staining dish to start a new culture among uninfested larvae. Best results were obtained with third and fourth instars immediately following ecdyses. According to Stryker (1966) this stage is desired because the integument was soft and easily pierced, and larvae near ecdyses secreted an oily liquid which killed the mites.

At 7-day intervals (the period needed for newly-born female mites to begin producing young) new wax moth larvae were added to feed the next generation of mites.

Miticides. So that the miticides could be added directly to the grain used to culture insects, only dust and wettable powder formulations* were tested.

Miticides used were:

Dessin 50% Wettable Powder (or WP)
(2-sec. butyl-4, 6-dinitrophenyl isopropyl carbonate)
Kelthane 18.5% WP
(4,4'-dichloro-a- (tri=chloromethyl) benzhydrol)
Morestan 25% WP
(6-methyl-2,3-quinoxaline=dithiol cyclic S,S-dithio=carbonate)
Morocide 50% WP
(2-sec-butyl-4, 6-dinitrophenyl 3-methyl-2-butenoate)
Pentac 50% WP
(decachlorobi-2, 4-cyclopentadien-1-yl)
Tedion 25% WP
(p-chlorophenyl 2,4,5-tri=chlorophenyl sulfone)
UC 20047A 50% WP
(exo-3-chloro-endo-2-norbornanance o-(Methylcarbamoyl) oxime)
Morocide 4% Dust
Tedion 3% Dust
Sulfur 100% Powder

Rates used in the tests were in ppm of active ingredients. Rates for dusts were lower than for wettable powder because excessive amounts of the dust were required to provide equal ppm of active materials. Sulfur powder was used full-strength in separate tests using the same methods.

EFFECTS OF MITICIDES ON ANGOUMOIS GRAIN MOTHS

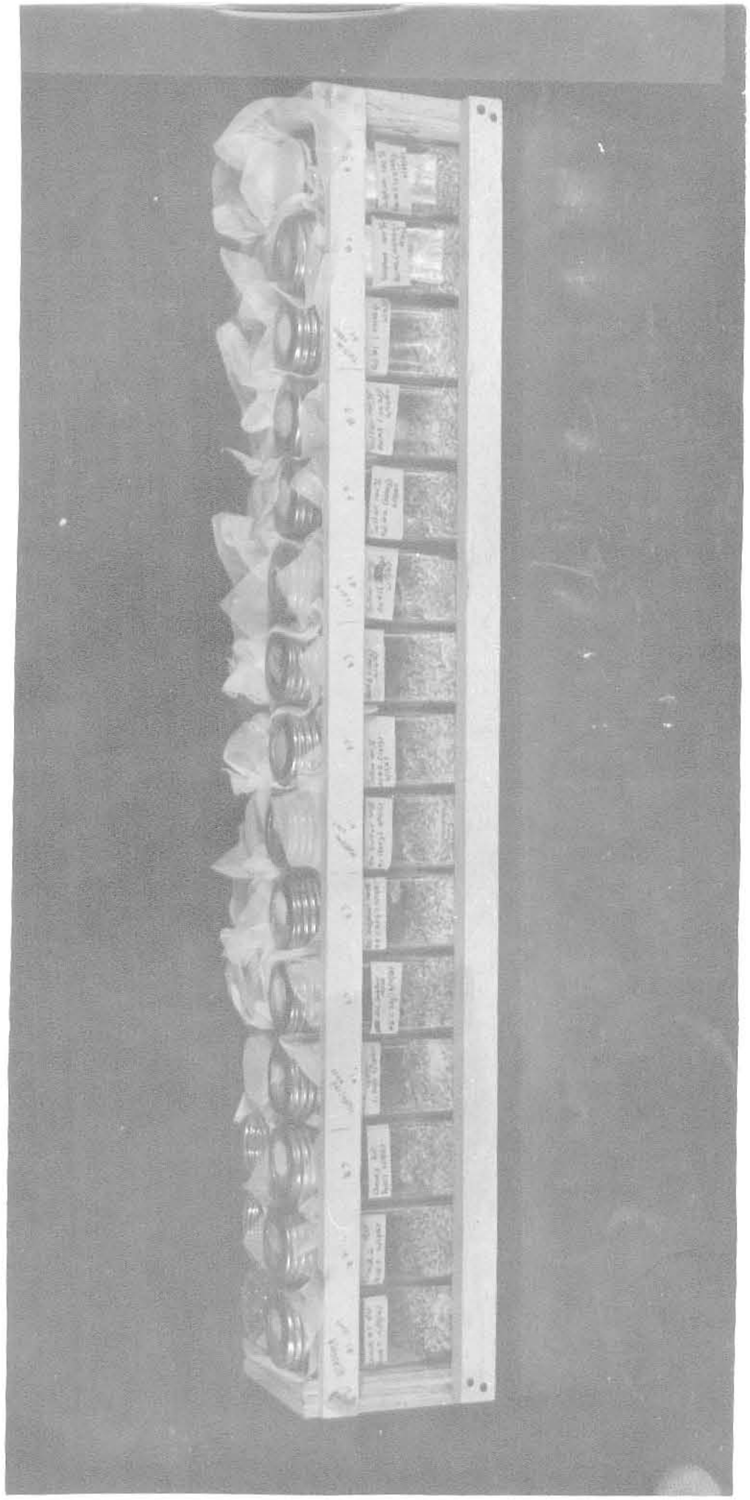
Materials and Methods. Thirty gm of hard red winter wheat at 13% moisture content were placed in each of 30 square glass jars (3.8 cm X 3.8 cm X 8.9 cm) which filled each to an approximate depth of 3.8 cm (Plate III). The amount of miticide to give the desired concentration was than added to each jar and mixed thoroughly with the grain. The treatments were replicated 3 times. The rates of wettable powder were 520 ppm, 260 ppm, and 130 ppm; rates of dusts used were 335 ppm, 163 ppm, and 84 ppm. Sulfur

*All formulations except Sulfur listed under their trade names.

EXPLANATION OF PLATE III

Jars (3.8 cm X 3.8 cm X 8.9 cm) of miticide treated grain used to determine the effect of miticide on Angoumois grain moths and rice weevils.

PLATE III



powder was tested at 4,167 ppm, 2,083 ppm, and 1,042 ppm in a separate test with a separate check. There were 3 untreated control jars.

Twenty unsexed newly-emerged Angoumois grain moths were placed in each jar giving a total of 60 per treatment. The jars were placed in a rearing room under constant conditions of 27 ±1°C and 70 ±3% RH.

Mortality records were taken after 3 days, when most eggs were already laid and natural mortality wasn't a major factor. The surviving moths were left in the jar. Progeny were counted and removed at 35, 40, 45, and 60 days after initiation of the test.

Discussion and Results. In the lowest rates of Morestan 25% WP and Tedion 25% WP moth survival was the same as in the check (Table 1). Pentac 50% WP, Dessin 50% WP, and Tedion 3% dust at most doses killed all the moths within 3 days. Moth survival in sulfur was almost identical to the check.

Tedion 25% WP, Kelthane 18.5% WP, and Morocide 4% dust allowed the most progeny to develop at each concentration (Table 2). This is consistant with the adult survival data except that Morestan allowed no progeny to develop.

EFFECTS OF MITICIDES ON RICE WEEVILS

Materials and Methods. The media were prepared as for the Angoumois grain moth tests (Plate III). Each miticide wettable powder was tested at 2,080 ppm, 1,040 ppm, 520 ppm, and 260 ppm. Each dust was tested at 670 ppm, 335 ppm, 163 ppm, and 84 ppm. In a separate test, sulfur powder was tested at 8,333 ppm, 4,167 ppm, 2,083 ppm, and 1,042 ppm. These rates are higher than for the Angoumois grain moth tests because preliminary tests

Table 1. Number of newly-emerged Angoumois grain moths surviving after 3 days in miticide-treated grain.

WETTABLE POWDER

	Rep*	Rate in ppm		
		520 ppm	260 ppm	130 ppm
Check	1	20	16	13
(No miticide)	2	16	18	17
	3	11	18	15
	Avg. %	78.3	86.7	75.0
Morestan 25%	1	7	13	15
	2	6	11	14
	3	11	9	17
	Avg. %	40.0	55.0	76.7
Tedion 25%	1	11	5	15
	2	11	1	16
	3	11	4	15
	Avg. %	55.0	16.7	76.7
Kelthane 18.5%	1	0	3	6
	2	3	1	7
	3	0	3	8
	Avg. %	5.0	11.7	35.0
Morocide 50%	1	0	0	2
	2	0	0	3
	3	0	0	2
	Avg. %	0.0	0.0	11.7
UC 20047A 50%	1	0	0	1
	2	0	0	1
	3	0	0	1
	Avg. %	0.0	0.0	5.0
Pentac 50%	1	0	0	0
	2	0	0	0
	3	0	0	0
	Avg. %	0.0	0.0	0.0
Dessin 50%	1	0	0	0
	2	0	0	0
	3	0	0	0
	Avg. %	0.0	0.0	0.0

*Twenty moths per replicate with 3 replicates per treatment.

Table 1. (Continued)

DUST

	Rep	Rate in ppm		
		335 ppm	168 ppm	84 ppm
Morocide 4%	1	3	0	2
	2	5	2	4
	3	0	0	3
	Avg. %	13.3	3.3	15.0
Tedion 3%	1	0	0	0
	2	0	0	0
	3	0	0	0
	Avg. %	0.0	0.0	0.0

SULFUR POWDER

	Rep*	Rate in ppm		
		4,167 ppm	2,083 ppm	1,042 ppm
Check	1	19	18	19
(No miticide)	2	18	20	18
	3	20	19	20
	Avg. %	95.0	95.0	95.0
Sulfur 100%	1	18	19	18
	2	17	19	19
	3	15	19	20
	Avg. %	83.3	95.0	95.0

Table 2. Number of progeny produced by Angoumois grain moths in miticide-treated grain.

WETTABLE POWDER

	Rep*	Rate in ppm		
		520 ppm	260 ppm	130 ppm
Check	1	341	316	354
(No miticide)	2	385	346	358
	3	264	351	307
	Total	990	1,013	1,019
Tedion 25%	1	190	245	247
	2	184	342	469
	3	206	254	254
	Total	580	841	970
Kelthane 18.5%	1	7	28	72
	2	10	26	110
	3	10	54	69
	Total	27	108	251
Morocide 50%	1	0	1	4
	2	0	7	13
	3	0	0	0
	Total	0	8	17
Pentac 50%	1	0	0	14
	2	0	0	0
	3	0	0	7
	Total	0	0	21
UC 20047A 50%	1	0	2	3
	2	0	1	10
	3	1	0	0
	Total	1	3	13
Morestan 25%	1	0	2	0
	2	0	0	0
	3	0	2	0
	Total	0	4	0
Dessin 50%	1	0	0	0
	2	0	0	0
	3	0	0	0
	Total	0	0	0

*Twenty parent moths per replicate with 3 replicates per treatment.

Table 2. (Continued)

DUST

	Rep	Rate in ppm		
		335 ppm	168 ppm	84 ppm
Morocide 4%	1	8	0	87
	2	79	5	123
	3	0	3	215
	Total	87	8	425
Tedion 3%	1	0	4	29
	2	0	2	18
	3	0	0	6
	Total	0	6	53

SULFUR POWDER

	Rep	Rate in ppm		
		4,167 ppm	2,083 ppm	1,042 ppm
Check (No miticide)	1	273		
	2	325		
	3	318		
	Total	916		
Sulfur 100%	1	282	253	382
	2	197	291	349
	3	233	309	327
	Total	712	853	1,058

indicated that the rice weevil was more tolerant to the miticides used. A jar with untreated wheat served as a control. Each treatment and control was replicated 3 times.

Ten males and 10 females of newly-emerged rice weevils were placed in each jar. The weevils had been sexed according to snout characteristics. After 7 days, surviving and dead weevils were removed and counted. At 35, 40, 50, and 60 days after introduction of adults, live and dead progeny were counted and removed.

Discussion and Results. The three WP miticides and the miticide dust in which survival was greatest were Tedion WP, Morocide WP, Dessin WP, and Morocide dust (Table 3). Survival in Tedion 25% WP, Morocide 50% WP, and Dessin 50% WP was 18.3, 0.0, and 0.0% at 2,080 ppm rate; 85.0, 25.0, and 0.0% at 1,040 ppm; 98.3, 60.0, and 16.7% at 520 ppm; and 76.7, 76.7, and 45.0% at 265 ppm. In Morocide 4% dust tests survival was 15.0, 48.3, 83.3, and 100.0% at 670, 335, 168, and 84 ppm rates, respectively. Survival in sulfur powder was 95.0, 100.0, 98.3, and 98.3 at 8,333, 4,167, 2,080 and 1,040 ppm, respectively.

The greatest numbers of progeny were produced (Table 4) in the same miticides in which adult survival was greatest (Tedion WP, Morocide WP, Dessin WP, and Morocide dust). Progeny production in the check averaged 629 per 60 parent weevils. Progeny production in Tedion WP, Morocide WP, and Dessin WP numbered 74, 0, and 0 at 2,080 ppm rate; 367, 136, and 14 at 1,040 ppm; 492, 418, and 115 at 520 ppm; and 495, 365, and 264 at 260 ppm. In Morocide dust tests the numbers of progeny produced were 48, 273, 376, and 363 at 670, 335, 168, and 84 ppm, respectively.

In a separate test using sulfur the numbers of progeny for all

Table 3. Number of newly-emerged parent rice weevils surviving after a 7-day oviposition period in miticide-treated grain.

WETTABLE POWDER

	Rep*	Rate in ppm			
		2,080 ppm	1,040 ppm	520 ppm	265 ppm
Check	1	9	20	20	20
(No miticide)	2	12	20	20	20
	3	15	20	20	19
	Avg. %	60.0	100.0	100.0	98.3
Tedion 25%	1	4	18	20	8
	2	2	17	20	20
	3	5	16	19	18
	Avg. %	18.3	85.0	98.3	76.7
Morocide 50%	1	0	5	6	15
	2	0	6	14	15
	3	0	4	16	16
	Avg. %	0.0	25.0	60.0	76.7
Dessin 50%	1	0	0	0	6
	2	0	0	5	11
	3	0	0	5	10
	Avg. %	0.0	0.0	16.7	45.0
Pentac 50%	1	0	0	2	5
	2	0	2	6	5
	3	0	0	0	6
	Avg. %	0.0	3.3	13.3	26.7
Kelthane 18.5%	1	0	1	3	4
	2	0	0	1	1
	3	0	0	0	0
	Avg. %	0.0	1.7	6.7	8.3
UC 20047A 50%	1	0	0	0	0
	2	0	0	0	0
	3	0	0	0	0
	Avg. %	0.0	0.0	0.0	0.0
Morestan 25%	1	0	0	0	0
	2	0	0	0	0
	3	0	0	0	0
	Avg. %	0.0	0.0	0.0	0.0

*Ten males and 10 females per replicate with 3 replicates.

Table 3. (Continued)

DUST

	Rep	Rate in ppm			
		670 ppm	335 ppm	168 ppm	84 ppm
Morocide 4%	1	3	16	17	20
	2	5	14	17	20
	3	1	17	16	20
	Avg. %	15.0	48.3	83.3	100.0
Tedion 3%	1	0	0	0	0
	2	0	0	0	0
	3	0	0	0	0
	Avg. %	0.0	0.0	0.0	0.0

SULFUR POWDER

	Rep	Rate in ppm			
		8,333 ppm	4,167 ppm	2,083 ppm	1,042 ppm
Check (No miticide)	1	19			
	2	20			
	3	18			
	Avg. %	95.0			
Sulfur 100%	1	19	20	20	20
	2	18	20	20	19
	3	20	20	19	20
	Avg. %	95.0	100.0	98.3	98.3

Table 4. Number of progeny of adult rice weevils 50 days after their introduction into miticide-treated grain.

WETTABLE POWDER

	Rep*	Rate in ppm			
		2,080 ppm	1,040 ppm	520 ppm	265 ppm
Check (No miticide)	1	114	272	395	289
	2	126	113	238	194
	3	175	259	206	137
	Total	415	644	839	620
Tedion 25%	1	32	115	92	216
	2	12	117	195	112
	3	30	135	205	167
	Total	74	367	492	495
Morocide 50%	1	0	32	136	92
	2	0	54	157	115
	3	0	50	125	158
	Total	0	136	418	365
Dessin 50%	1	0	2	24	88
	2	0	12	54	95
	3	0	0	37	81
	Total	0	14	115	264
Pentac 50%	1	0	11	17	16
	2	0	19	63	72
	3	0	1	1	34
	Total	0	31	81	122
Kelthane 18.5%	1	1	4	15	46
	2	1	0	18	42
	3	0	0	3	22
	Total	2	4	36	110
UC 20047A 50%	1	0	0	0	0
	2	0	0	0	0
	3	0	0	0	20
	Total	0	0	0	20
Morestan 25%	1	0	0	0	0
	2	0	0	0	0
	3	2	0	1	0
	Total	2	0	1	0

*Ten males and ten females per replicate with 3 replicates.

Table 4. (Continued)

DUST

	Rep	Rate in ppm 670 ppm	335 ppm	168 ppm	84 ppm
Morocide 4%	1	11	75	136	140
	2	36	78	124	140
	3	1	120	116	83
	Total	48	273	376	363
Tedion 3%	1	0	0	0	15
	2	0	0	0	17
	3	0	0	0	1
	Total	0	0	0	33

SULFUR POWDER

	Rep	Rate in ppm 8,333 ppm	4,167 ppm	2,083 ppm	1,042 ppm
Check (No miticide)	1	282			
	2	132			
	3	188			
	Total	602			
Sulfur 100%	1	204	149	141	189
	2	239	135	216	281
	3	345	282	133	208
	Total	788	566	490	678

replicates were 788, 566, 490, and 678 at 8,333, 4,167, 2,083, and 1,042 ppm, respectively. Total number of progeny in the check was 602.

EFFECTS OF MITICIDES ON *PYEMOTES* SP.

Materials and Methods. This test was designed to determine the relative effectiveness of the miticides on the mites alone.

Two concentric circles (2.5 cm and 3.8 cm diam) were drawn with pencil (Plate IV) in the center of each 9 cm diam filter paper disk (semi-crumpled, rapid). Each disk was placed in a pint jar 1/3-full of miticide (dry and undiluted). The jar was capped tightly and shaken vigorously by hand for 15 seconds and allowed to settle for 1 min. The paper was then removed, shaken 3 times, and placed in an appropriately labeled Petri dish. Each treatment was replicated 3 times as was the untreated control.

A vaseline mite barrier was applied near the top on the inside of the Petri dish. Three penultimate Angoumois grain moth larvae (removed from wheat kernels) were placed individually in gelatin capsules (#3) which were glued in each dish equidistant from each other around the perimeter of the filter paper. In each end of each capsule was a small hole to allow mites access to the Angoumois grain moth larva.

A wax moth larva with 80-120 attached gravid female mites was placed in a gelatin capsule (#3) which was glued in the center of the treated filter paper in the Petri dish (Plate IV). The capsule had several holes to allow newly-born mites to escape. A wax moth larva was used for the infestation rather than an Angoumois grain moth larva because the [illegible] generation of mites would readily leave the wax moth larva.

After 8 days, ample time for production of numerous progeny but before

EXPLANATION OF PLATE IV

Fig. 1. Petri dish with Morocide 4% dust on filter paper. Pyemotes infested wax moth larva in center capsule with AGM larvae in 3 small outer capsules. Accumulation of dead mites around center capsule appears as orange dust.

Fig. 2. Three Petri dishes showing comparison of no accumulation of dead mites for check to the left, to a small accumulation for Tedion 3% dust in the middle dish, to a large accumulation of dead mites in the right dish of 4% Morocide.

PLATE IV

Fig. 1

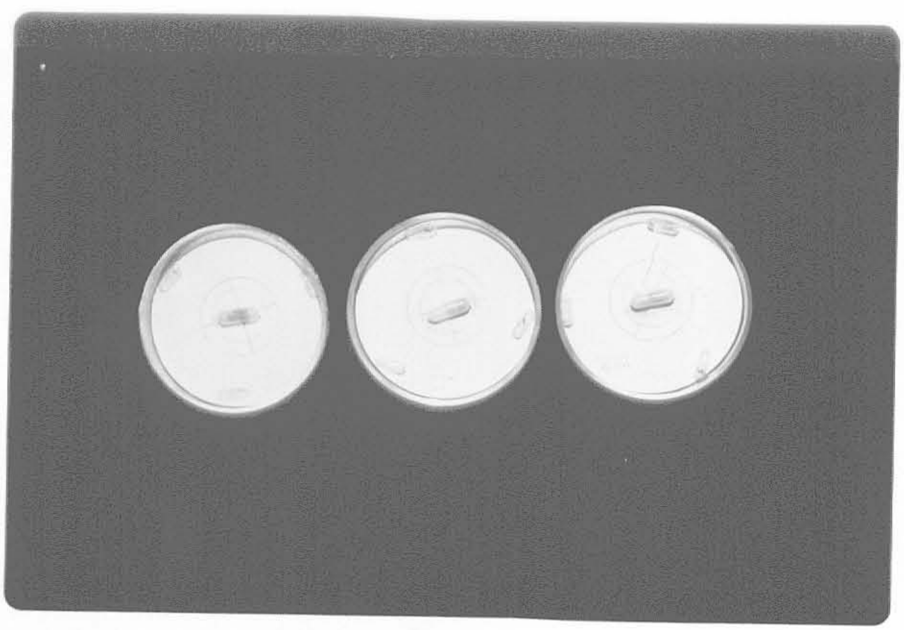


Fig. 2

Table 5. Ability of Pyemotes sp. mites to move from the center to the outside of miticide-treated filter papers and then parasitize Angoumois grain moth larvae (or AGM).

Miticide	Rep	% of dead mites: In 2.5 cm circle	Between 2.5 cm & 3.8 cm circle	Between 3.8 cm & edge of paper		AGM larvae parasitized (of 3)	# gravid mites on AGM larvae
Check	1	20	0	80		2	38
(No	2	10	0	90		3	59
miticide)	3	10	0	90		3	36
Avg.		13.3	0	86.7	Total	8	133
Morestan	1	95	4	1		0	0
25% WP	2	88	10	2		0	0
	3	90	9	1		0	0
Avg.		91.0	7.7	1.3	Total	0	0
Kelthane	1	95	4	1		0	0
18.5% WP	2	85	12	3		0	0
	3	80	15	5		0	0
Avg.		86.7	10.3	3.0	Total	0	0
Morocide	1	80	15	5		0	0
4% Dust	2	91	8	1		0	0
	3	75	15	10		0	0
Avg.		82.0	12.7	5.3	Total	0	0
Morocide	1	85	10	5		0	0
50% WP	2	60	30	10		0	0
	3	65	25	10		0	0
Avg.		70.0	21.7	8.3	Total	0	0
Dessin	1	95	5	0		0	0
50% WP	2	40	25	35		0	0
	3	75	10	15		0	0
Avg.		70.0	13.3	16.7	Total	0	0
Tedion	1	65	5	30		0	0
3% Dust	2	85	10	5		0	0
	3	55	30	15		0	0
Avg.		68.3	15.0	16.7	Total	0	0

Table 5. (Continued)

Miticide	Rep	% of dead mites: In 2.5 cm circle	Between 2.5 cm & 3.8 cm circle	Between 3.8 cm & edge of paper	AGM larvae parasitized (of 3)	# gravid mites on AGM larvae
UC 20047A	1	65	20	15	0	0
50% WP	2	60	20	20	1	22
	3	30	10	60	3	54
Avg.		51.7	16.7	31.7	Total 4	76
Tedion	1	70	15	15	3	33
25% WP	2	30	20	50	3	88
	3	40	30	30	3	68
Avg.		46.7	21.7	31.7	Total 9	189
Pentac	1	80	18	2	0	0
50% WP	2	20	10	70	0	0
	3	20	10	70	2	16
Avg.		40.0	12.7	47.3	Total 2	16
Sulfur	1	30	5	65	3	47
100% Powder	2	20	5	75	3	57
	3	20	5	75	3	89
Avg.		23.3	5.0	71.7	Total 9	193

a second generation, estimates were made of the percentages of mites found dead within the 2.5 cm circle, between this circle and the 3.8 cm circle and beyond the 3.8 cm circle. The numbers of mites which had reached the Angoumois grain moth larvae and became gravid were recorded.

Discussion and Results. As expected, most of the newly-born mites left the center capsule to search for a host. As they crawled on the treated filter paper, many were killed by some of the miticides. Where dead mites accumulated, the appearance was as a light brown "dust" (Plate IV, Fig. 1).

It was assumed that the mites would traverse less of the filter paper treated with the most effective miticides. In Plate IV, Fig. 2 the dead mites accumulated near the center capsule could be seen on miticide-treated paper but in the check they had dispersed so much that they were not visible with the naked eye except where they had accumulated in the petroleum jelly barrier on the walls of the Petri dish.

The 3 most effective miticides in this test were Morestan WP, Kelthane WP, and Morocide dust which killed 91.0, 86.7, and 82.0% within the 2.5 cm diam circle (Table 5). Others were nearly as effective. None of the Angoumois grain moth larvae in the six most effective treatments had gravid female mites on them. Those treatments included Morestan WP, Kelthane WP, Morocide dust, Morocide WP, Dessin WP, and Tedion dust.

EFFECTIVENESS OF SELECTED MITICIDES IN PREVENTING *PYEMOTES* SP. INFESTATION OF ANGOUMOIS GRAIN MOTH CULTURES

Materials and Methods. The miticides giving the best results in the preceding tests with Angoumois grain moths and mites were used in this test at the following rates:

Kelthane 18.5% WP .... 260 ppm & 130 ppm
Morocide 4% Dust .... 168 ppm & 84 ppm
Tedion 25% WP .... 520 ppm & 260 ppm

The appropriate amount of each miticide was mixed with 300 gm of hard red winter wheat at 13% moisture. Sixty gm of the miticide-treated grain were placed in each wide-mouth pint jar.

Wheat kernels containing Angoumois grain moth larvae of about the penultimate instar were selected from laboratory cultures with use of X-ray radiographs. The selected wheat kernels were marked for later identification with a small spot of India ink. Thirty marked kernels were randomly mixed through the treated grain in each pint jar. A wax moth larva infested with 100 to 200 gravid female mites was placed in a #00 gelatin capsule then positioned on top of the wheat in each jar. Numerous holes were in each capsule to allow newly-born mites to escape. Each treatment and untreated control was replicated 3 times.

The jars were placed in a 91.5 cm X 91.5 cm X 91.5 cm rearing unit with 27 ±1°C and 70 ±3% RH. After 12 days (the amount of time to allow a third generation of mites to become attached and gravid) the jars were put in a freezer for 2 days to kill all insects and mites. It was necessary to kill the insects and mites to prevent contamination of the X-ray machine which was used daily. The marked kernels in each jar were X-rayed. The brood pouches of gravid female mites were identifiable in the radiographs (Plate II, Fig. 1).

<u>Discussion</u> <u>and</u> <u>Results</u>. None of the miticides at the rates used gave 100% control. This can be attributed to the lower concentrations necessary to allow moth survival. All of the higher rates reduced the incidence of parasitism by an average of at least 60%, with Morocide 4% dust (168 ppm) reducing the infestation an average of 75% below that of the check.

Table 6. Effectiveness of miticides in preventing *Pyemotes* sp. from parasitizing Angoumois grain moth larvae in culture wheat as determined by successful moth emergence and X-ray radiographs of kernels containing insect larvae.

Miticide in wheat*	Rep**	No.*** moths emerged	Larvae not par.**** (X-ray determ.)	Total insects not par.	Larvae par. (X-ray determ.)	% larvae par.
Check	1	0	15	15	15	50.0
(No	2	4	12	16	14	46.7
miticide)	3	13	3	16	14	46.7
Avg.		5.7	10.0	15.7	14.7	48.9
Morocide	1	18	7	25	5	16.7
4% Dust	2	26	4	30	0	0.0
(168 ppm)	3	18	7	25	5	16.7
Avg.		20.7	6.0	26.7	3.3	11.1
Morocide	1	17	9	26	4	13.3
4% Dust	2	17	4	21	9	30.0
(84 ppm)	3	14	3	17	13	43.3
Avg.		16.0	5.3	21.3	8.7	28.9
Kelthane	1	13	9	22	8	26.7
18.5% WP	2	18	9	27	3	6.7
(260 ppm)	3	18	11	29	1	3.3
Avg.		16.3	9.7	26.0	4.0	13.3
Kelthane	1	12	9	21	9	30.0
18.5% WP	2	15	6	21	9	30.0
(130 ppm)	3	14	7	21	9	30.0
Avg.		13.7	7.3	21.0	9.0	30.0
Tedion	1	19	8	27	3	10.0
25% WP	2	8	15	23	7	23.3
(520 ppm)	3	14	9	23	7	23.3
Avg.		13.7	10.7	24.3	5.7	18.9
Tedion	1	5	13	18	12	40.0
25% WP	2	4	10	14	16	53.3
(260 ppm)	3	6	11	17	13	43.3
Avg.		5	11.3	16.3	13.7	45.5

*ppm active ingredient.
**Thirty moth-infested kernels per replicate.
***Emerged prior to freezing.
****Parasitized.

EFFECTIVENESS OF SELECTED MITICIDES IN PREVENTING *PYEMOTES* SP. INFESTATION OF RICE WEEVIL IN CULTURES

Materials and Methods. The miticides giving the best results in the preceding tests with rice weevils and mites were used in this test at the following rates:

Morocide 4% Dust	168 ppm & 335 ppm
Morocide 25% WP	520 ppm & 1,040 ppm
Dessin 50% WP	265 ppm
Tedion 25% WP	520 ppm & 1,040 ppm

The media were prepared as in the Angoumois grain moth culture test. Wheat kernels containing preultimate rice weevil larvae were selected from laboratory cultures with use of X-ray radiographs. The selected kernels were marked for later identification with a small spot of India ink. Thirty marked infested kernels were randomly mixed through the treated grain in each pint jar. Two Angoumois grain moth larvae were placed in each jar. They were placed in gelatin capsules and were infested with approximately 50 gravid female mites each. Holes had been cut into the capsules to allow newly-born mites to escape into the grain. Each treatment and untreated control were replicated 3 times.

The jars were placed in a 91.5 cm X 91.5 cm X 91.5 cm rearing unit with 27 $\pm 1^{o}$C temperature and 70 ± 3% RH. After 14 days the jars were removed and put in the freezer for two days to kill all insects and mites. Because of the slower development of mites on weevils, 14 days were necessary to allow the second generation of female mites to become gravid. The marked kernels with no weevil emergence holes were dissected rather than X-rayed and the number of infested and uninfested larvae were counted. Plate V shows a dissected kernel which contained an Angoumois grain moth larva with gravid mites attached. Dissection of the weevil-infested kernels

EXPLANATION OF PLATE V

Dissected kernel of wheat showing gravid female *Pyemotes* mites attacking Angoumois grain moth larva.

PLATE V

Table 7. Effectiveness of miticides in preventing *Pyemotes* sp. parasitism of rice weevils in culture wheat as determined by successful weevil emergence and by dissection of kernels containing insect larvae.

Miticide in wheat*	Rep**	No.*** moths emerged	Larvae not par.**** (X-ray determ.)	Total insects not par.	Larvae par. (X-ray determ.)	% larvae par.
Check	1	19	9	28	2	6.7
(No	2	22	5	27	3	10.0
miticide)	3	20	7	27	3	10.0
Avg.		20.3	7.0	27.3	2.7	8.8
Morocide	1	26	4	30	0	0.0
4% Dust	2	24	6	30	0	0.0
(168 ppm)	3	24	6	30	0	0.0
Avg.		24.7	5.3	30.0	0.0	0.0
Morocide	1	22	8	30	0	0.0
4% Dust	2	20	10	30	0	0.0
(335 ppm)	3	21	9	30	0	0.0
Avg.		21.0	9.0	30.0	0.0	0.0
Dessin	1	26	4	30	0	0.0
50% WP	2	21	[illegible]	30	0	0.0
(265 ppm)	3	19	11	30	0	0.0
Avg.		22.0	8.0	30.0	0.0	0.0
Morocide	1	24	5	29	1	3.3
50% WP	2	25	5	30	0	0.0
(520 ppm)	3	22	8	30	0	0.0
Avg.		23.7	6.0	29.7	0.3	1.1
Morocide	1	21	9	30	0	0.0
50% WP	2	26	4	30	0	0.0
(1,040 ppm)	3	27	3	30	0	0.0
Avg.		24.7	5.3	30.0	0.0	0.0
Tedion	1	24	4	28	2	6.7
25% WP	2	24	5	29	1	3.3
(520 ppm)	3	18	12	30	0	0.0
Avg.		22.0	7.0	29.0	1.0	3.3
Tedion	1	23	6	29	1	3.3
25% WP	2	19	8	27	3	10.0
(1,040 ppm)	3	20	10	30	0	0.0
Avg.		20.7	8.0	28.7	1.3	4.4

*Ppm active ingredient.
**Thirty weevil-infested kernels per replicate.
***Emerged prior to freezing.
****Parasitized.

was necessary for more accurate records, since the population density of mites was too small to easily detect the gravid mite brood pouches on a radiograph.

Discussion and Results. With such low levels of mite population intensities in the checks it is difficult to evaluate this information. Mite population intensities were usually observed to be lower in rice weevil cultures during the epidemics in the rearing rooms. Rice weevils seal their oviposition holes with egg plugs which offer a greater degree of resistance to entry by the Pyemotes mites than the entry holes made by Angoumois grain moth larvae. Possibly only when the egg plugs fall out or are loosened can the mites gain access. The mites seem to be unequipped to eat their way through to the larvae. However, in this test several miticides allowed no parasitism. They were Morocide 4% dust at 168 ppm and 335 ppm, Dessin 50% WP at 265 ppm, and Morocide 50% WP at 1,040 ppm.

SUMMARY AND CONCLUSIONS

A Pyemotes mite infestation occurring in an insect rearing room may cause 1 to 3 months of lost research time while mite-free cultures are being restored. Thus, an attempt was made to find an effective means of destroying and/or preventing mites in insect cultures without loss of insect populations and valuable research time.

Various miticide dry formulations (wettable powders and dusts) were mixed directly in the insect wheat culture media. Three steps were used with Angoumois grain moths and rice weevils as the test insects.

First, the 9 different miticide formulations were screened to determine their effect on the mortality of adults and on the number of progeny they produced. Angoumois grain moths were more susceptible to the miticides used than the rice weevils. Thus, lower rates were used in subsequent testing of that species. Accordingly, the degree of mite control was less in cultures involving this insect than in those with rice weevils. This is important since the mite is most destructive in the Angoumois grain moth cultures and may completely destroy them.

The second step involved testing the effectiveness of the miticides against the mites alone. All but 3 of the miticides killed the mites before they could attack the Angoumois grain moth larvae around the perimeter of the treated filter paper (Table 5). Sulfur which was also used offered no control, killing no more mites than those found dead in the check.

Finally, the effectiveness of selected miticides (determined by the first 2 steps) in controlling mites under culture conditions was tested. The results (Table 6) indicated that 3 miticide formulations (Morocide 4% dust at 168 ppm, Kelthane 18.5% wettable powder at 260 ppm, and Tedion 25% wettable powder at 520 ppm) reduced the mite infestation 65 to 80% below that of the control infestation in Angoumois grain moth cultures. As previously stated, the rice weevil results in Table 7 are difficult to evaluate because of the low level of mite parasitism in the control. When Pyemotes infestations have shown up in the rearing room they build up higher populations and are more destructive in the Angoumois grain moth cultures. Several miticides which allowed no parasitism with little weevil population reduction included Morocide 4% dust at 168 ppm and 335 ppm, Dession 50% WP at 265 ppm, and Morocide 50% WP at 1,040 ppm.

It can be concluded that mites in Angoumois grain moth cultures can be greatly reduced but not eliminated by using certain of the tested miticides directly in the culture wheat. This means of control in rice weevil cultures may completely eliminate a Pyemotes mite infestation.

ACKNOWLEDGMENTS

The author expresses his sincere appreciation particularly to Dr. Robert B. Mills for his patience and valuable guidance as the author's major instructor, and to Professor D. A. Wilbur for his guidance and help.

Others who assisted include James A. Webster, Glen Swoyer, Robert Stryker, and June Biery.

This research was supported in part by PHS grant FD 00065-11 formerly UI 00095 and EF 00114.

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EFFECTS OF VARIOUS MITICIDES UPON AN ECTOPARASITIC MITE (*PYEMOTES* SP.) IN RICE WEEVIL AND ANGOUMOIS GRAIN MOTH CULTURES

by

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B. S., Kansas State University, 1966

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Entomology

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1970

Various miticide dry formulations were tested in an attempt to find an effective means of destroying and/or preventing ectoparasitic mites (Pyemotes sp.) in rice weevil and Angoumois grain moth wheat cultures.

Formulations tested were: Dessin 50% wettable powder (or WP), Kelthane 18.5% WP, Morestan 25% WP, Morocide 50% WP, Tedion 25% WP, UC 20047A 50% WP, Morocide 4% dust, Tedion 3% dust, and Sulfur 100% powder.

First, the 9 different miticide formulations were screened on the two test insects to determine their effect on the mortality of adults and on the number of progeny they produced. Angoumois grain moths were more susceptible to the miticides used than the rice weevils. Thus, lower rates were used in subsequent testing of the species.

The second step involved testing the effectiveness of the 9 miticides against the mites alone.

Finally, the effectiveness of selected miticides (determined by the first 2 steps) in controlling the mites under culture conditions was tested. The results indicated that 3 miticide formulations (Morocide 4% dust at 168 ppm, Kelthane 18.5% WP at 260 ppm, and Tedion 25% WP at 520 ppm) reduced the mite infestation 65 to 80% below that of the control infestation in Angoumois grain moth cultures. The rice weevil results were difficult to evaluate because of the low level of mite parasitism in the control. However, miticides which allowed no parasitism with little weevil population reduction included Morocide 4% dust at 168 ppm and 335 ppm, Dessin 50% WP at 265 ppm, and Morocide 50% WP at 1,040 ppm.