STERILIZATION OF THE BULB MITE, RHIZOGLYPHUS ECHINOPUS (F. et R.) (ACARIDA: ACARIDAE), WITH GAMMA RADIATION

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Abstract

The age of the eggs of the bulb mite, *Rhizoglyphus echinopus* (F. et R.), at the time of irradiation and the dosage of gamma radiation had a profound effect on their hatchability. A significant portion of older eggs developed to the adult stage. However, the sex ratio in these adults was strongly male-biased. The fertility of mites developed from irradiated deutonymphs was highly reduced. A reduction in fecundity ranged from 90 to 100% when the inert deutonymphs were irradiated with a dose of 0.2 kGy or higher. Viability of eggs laid by mites emerged from treated deutonymphs was very low. At a 0.1 kGy, ca. 37% eggs were dead, but at 0.2 kGy was 86.5% mortality of eggs. Fecundity of the bulb mite was greatly affected by gamma radiation when adults were treated with a dose of 0.1 kGy or higher. Mites irradiated as adults produced eggs longer than mites treated as inert deutonymphs Females of the bulb mite were clearly more radiosensitive than males: the sterilizing dose of gamma radiation was found to be 0.4-0.5 kGy for females, but for the males it ranged between 0.5 and 0.6 kGy.

INTRODUCTION

Chemical fumigants have been used effectively for many years around the world for pest disinfestation of agricultural commodities. However, controversy over the use of these chemicals has arisen in recent years (Ignatowicz, 1988). Fumigants do not penetrate some commodities in sufficient concentration to control some pests. Chemical treatments may have deleterious effects on the agricultural products or may leave undesirable residues (Ignatowicz, 1981). The development of resistance to insecticides or fumigants by insects and mites is yet another incentive for the development of alternative methods for pest control.

Irradiation, in the form of gamma radiation or accelerated electron beam, does not present these problems because it is a physical process. Disinfesting commodities by irradiation requires that the dosage be sufficient to sterilize or kill the most resistant pest present. If advantage is to be taken of the economic savings resulting from limiting the irradiation to the minimum effective dose, the sensitivities of pests to the treatment must be known.

Adequate information is available on dosage of ionizing radiation required to control most insect species that infest agricultural products. However, the mites - pests of stored products have not been studied extensively and little can be deducted about their relative radiosensitivity (Ignatowicz, 1983; 1986).

This paper deals with studies of the bulb mite, Rhizoglyphus echinopus (Fumouze et Robin), made to determine its sensitivity to gamma radiation from a Co-60 source. Preliminary results of this study were presented at the 29th Scientific Session of the Plant Protection Institute, Poznań, Poland (Ignatowicz and Wróblicka-Sysiak, 1989).

MATERIALS AND METHODS

The bulb mites were isolated from rotten onions in January 1987, and they have been maintained in a laboratory on brewer's yeast at room temperature and 89% R.H. Samples of the mites within the medium were irradiated with the cobalt-60 gamma rays using an irradiator of the type "RChM-gamma-20". Dose rate amounted 20 Gy per min. A Fricke dosemeter was used for calibration.

Studies on irradiation of adults of both sexes were initiated by selecting inert deutonymphs from stock colonies and holding them in separate cages as described by Boczek (1954). On the day following emergence, the adults were sexed and treated with Co-60 radiation. Adult males and females (24-48 hour old) were treated with the following doses of radiation: 0.0 (control), 0.1, 0.2, 0.25, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.2, 1.5, 1.8, and 2.1 kGy.

On the same day as the irradiation treatment, the irradiated mites were paired. During rearing and observation, the mites were kept in rearing cages supplied with food. The rearing cages were stored in darkness at 25±1°C and 85±5% R.H.

Every 1-3 days the number of eggs laid by females was counted, removed from the cages, and food added. Fecundity was recorded by counting the eggs laid by each female until death. The viability of these eggs was observed. Mortality of females and males was recorded.

Effects of gamma radiation on eggs and inert deutonymphs were studied using similar methods. Irradiated eggs and inert deutonymphs were allowed to reach the adult stage. Then males and females that emerged were paired and their fecundity, fertility and longevity observed.

In order to determine the dosage that sterilized males or females the following methods were adopted. The treated and untreated mites were paired according to the following combinations: (a) untreated females and untreated males (control), (b) untreated females and treated males, (c) treated females and untreated males, and (d) treated females and treated males. Fecundity, fertility and longevity of these mites was recorded.

RESULTS

Irradiation of eggs

Table I shows the influence of treatment age and dosage of gamma radiation on egg mortality. It is seen that the age of the eggs at the time of irradiation had a profound effect on their hatchability. The 0-2-day-old eggs were very sensitive to radiation, and the sensitivity to radiation of 0- to 1- and 1- to 2-day-old eggs was similar. A 0.1 kGy dose caused 63.6-67% mortality of these eggs whereas irradiation at 0.2 kGy resulted in 74.2-74.[illegible]% embryonic death. A dose of 0.3 kGy or higher prevented hatching following irradiation of 0- to 2-day-old eggs. The older eggs were resistant to radiation. None of the dose (0.1 to 0.5 kGy) could induce mortality of these eggs. Because of moderate mortality rates in larval and nymphal stages, a significant part of these (2-day old eggs) eggs developed to the adult stage. However, the sex ratio in these adults was strongly male-biased: only 1-5% females was recorded (Table II). These males were sterile; untreated females paired with males that emerged from eggs treated with 0.5 kGy were found to produce no eggs.

Irradiation of inert deutonymphs

Unsexed, intermediate-aged inert deutonymphs were used, and the sex ratio was about 1:1 in the emerging untreated adults (control). No difference in sensitivity between the sexes was indicated in the adults that emerged from treated inert deutonymphs. The sex ratio was also about 1:1.

Adults obtained from irradiated deutonymphs were paired, and production of eggs and their viability were recorded. Data obtained are summarized in Table III. The number of eggs laid by these mites decreased with an increase of the dosage ($r= -0.658$). All mites emerged from deutonymphs treated with 1.0 kGy were unfecund. As compared to the control, the fecundity of the bulb mites developed from irradiated deutonymphs was highly reduced. For example, adults emerged from deutonymphs treated with 0.35 kGy produced 93.6% eggs less than the control mites. A reduction in fecundity ranged from 90 to 100% when the inert deutonymphs were irradiated with a dose of 0.2 kGy or higher. Also, these mites produced significantly less eggs than the mites treated as adults.

Adults of the bulb mite emerged from inert deutonymphs irradiated with 0.2 kGy produced eggs during six weeks after the treatment. Those mites originating from deutonymphs given a 0.25 kGy or higher dose produced eggs during only 2 weeks after the treatment, being infecund thereafter.

Viability of eggs laid by mites emerged from treated deutonymphs was very low. At a 0.1 kGy dose, ca. 37% eggs were dead, but at 0.2 kGy was 86.5% mortality of eggs. Eggs laid by mites irradiated with a 0.25 kGy or higher dose failed to hatch (only occasionally a few eggs hatched at 0.35 kGy dosage).

Irradiation of both males and females

As shown in Table IV, the fecundity of the bulb mites was greatly affected by gamma radiation at a dose of 0.1 kGy or higher. Adult mites treated with 0.25 kGy produced 87% less eggs than the controls.

The treated pairs exhibited a great variability in sensitivity to radiation. Their fecundity ranged from 1 to 119, 24-114, and 1-64 eggs when males and females were treated with 0.25, 0.5, and 0.9 kGy, respectively.

Mites irradiated with 1.0 kGy laid a few eggs, but those treated with 1.2 kGy only occasionally produced the eggs. All pairs given a 1.5 kGy dose or higher were unfecund.

Mites irradiated as adults produced eggs longer than mites treated as inert deutonymphs. Males and females given 0.6 or 0.8 kGy laid eggs during the 1st, 2nd and 3rd week after the treatment, being unfecund thereafter.

Data on hatchability of eggs laid by treated adults are presented in Table IV. It is seen that all eggs laid by mites irradiated with 0.5 or higher dose were sterile. A single larva hatched from an egg produced by mite pairs treated with doses of 0.25, 0.3 and 0.4 kGy. In these cases, however, lethality of eggs was higher than 99.8%. A significant part of eggs laid by 0.1- or 0.2-kGy treated mites hatched. However, the viability of eggs was higher at 0.1 kGy than at a 0.2 kGy dose.

Viability of eggs laid by 0.1- or 0.2-kGy treated mites was low during the first days after irradiation. Later on, it reached a rather stable level. This indicates a quick post-radiation recovery in fertility by mites irradiated with low dosages of gamma radiation.

Larvae hatched from eggs laid by 0.1- and 0.2 kGy - treated mites were allowed to develop to the adult stage, and the sex ratio in progeny obtained was determined. A significant distortion of sex ratio (preponderance of males) in progeny that developed from eggs laid during the first 5 days after the treatment was found. It seems to be related with the lowered viability of eggs reported for the same period after irradiation.

Irradiation of males or females

When females were irradiated and mated to normal males, the reduction in their fecundity was lower than for the pairs in which only males were treated. At all treatment levels, the treated females mated to the treated males laid significantly more eggs than the irradiated females mated to either treated or untreated males (p 0.05) (Table V). The similar relationships were found for the mold mites treated with accelerated electrons (Ignatowicz, 1986).

Mortality of eggs produced by treated males and treated females was very high. Already, at 0.3 kGy treatment, pairs produced eggs which all were sterile. However, females treated with 0.3 kGy of gamma radiation laid about 30% viable eggs when mated to untreated males. In the opposite treatment combination, 16.6% eggs hatched.

When higher doses of gamma radiation were applied, hatchability of eggs produced by the treated females was very low (2%). Still, 19.2% eggs hatched in the opposite pairing combination.

Females irradiated with 0.5 kGy and mated to either treated or untreated males produced no viable eggs. When 0.5 kGy-treated males were paired with normal females, only 5.3% eggs produced were hatched.

Table I. Sensitivity of *R. echinopus* eggs to gamma radiation in dependance on their age at the treatment

Dose (kGy)	Age of eggs (days)							
	0-1		1-2		2-3		3-4	
	n	%	n	%	n	%	n	%
0.0	65	87.7	39	92.3	99	85.8	77	94.8
0.1	115	33.0	88	36.4	125	100.0	234	100.0
0.2	147	25.2	93	25.8	174	98.3	230	99.6
0.3	187	0.0	146	0.0	108	100.0	168	100.0
0.4	132	0.0	49	0.0	132	100.0	282	98.9
0.5	93	0.0	64	0.0	155	98.1	277	100.0

Explanations: n - number of eggs observed; % - percent of larvae hatched.

Table II. Sex ratio of the bulb mites, R. echinopus, developed from eggs irradiated with 0.1-0.5 kGy of gamma radiation (the eggs were 2-day-old at the treatment)

Dose (kGy)	Total number of progeny observed	Number of females	Percent of females
0.1	193	2	1.0
0.3	240	13	5.4
0.5	331	8	2.4
Control	427	221	51.8

Table III. Fecundity and fertility of *R. echinopus* mites treated with gamma radiation as inert deutonymphs

Dosage (kGy)	Number of mite pairs	Unfecund pairs		Fecundity[a]	Hatchability of eggs (%)
		number	%		
0.0	17	0	0.0	335.6±25.9	99.2
0.1	27	0	0.0	248.6±19.7	62.6
0.2	26	0	0.0	83.9±13.2	13.5
0.25	33	0	0.0	14.4±1.7	0.0
0.3	37	1	2.7	12.5±1.2	0.0
0.35	42	1	2.4	21.8±1.8	1.0
0.4	27	0	0.0	11.0±1.4	0.0
0.45	31	1	3.2	20.0±1.6	0.0
0.5	38	1	2.6	18.4±2.1	0.0
0.6	35	0	0.0	19.8±1.6	0.0
0.7	41	2	4.9	14.5±1.6	0.0
0.8	47	7	14.9	8.1±0.9	0.0
0.9	40	6	15.0	6.5±0.5	0.0
1.0	36	36	100.0	0	-

a) Number of eggs per fecund female; mean ± standard error.

Table IV. Fecundity and fertility of R. echinopus mites treated with gamma radiation as adults

Dosage (kGy)	Number of mite pairs	Unfecund pairs		Fecundity[a]	Hatchability of eggs (%)
		number	%		
0.0	17	0	0.0	335.6±25.9	99.2
0.1	29	0	0.0	261.0±23.3	30.6
0.2	25	0	0.0	104.8±5.4	0.4
0.25	37	0	0.0	43.6±3.4	0.2
0.3	33	0	0.0	30.5±2.2	0.0
0.4	21	0	0.0	65.6±2.6	0.0
0.5	50	0	0.0	59.7±2.4	0.0
0.6	40	0	0.0	58.8±2.7	0.0
0.7	15	0	0.0	38.2±2.8	0.0
0.8	37	3	8.1	29.6±2.5	0.0
0.9	27	1	3.7	25.6±2.9	0.0
1.0	31	2	6.5	33.1±2.6	0.0
1.2	30	29	96.7	5.0±0.0	0.0
1.5	28	28	100.0	0	-
1.8	31	31	100.0	0	-
2.1	26	26	100.0	0	-

a) Number of eggs per fecund female; mean ± standard error.

Table V. Fecundity and fertility of irradiated (T♀) or non-irradiated (U♀) females of the bulb mite, R. echinopus, paired with irradiated (T♂) or non-irradiated (U♂) males

Dosage (kGy)	Combination	Number of mite pairs	Fecundity[a]	Hatchability of eggs (%)
0.0	U♀ x U♂	17	335.6±25.9	99.2
0.3	T♀ x T♂	28	30.5±2.4	0.0
	T♀ x U♂	30	49.0±4.4	29.4
	U♀ x T♂	23	242.1±26.1	16.6
0.4	T♀ x T♂	21	65.6±2.6	0.0
	T♀ x U♂	27	32.1±3.3	2.0
	U♀ x T♂	24	99.0±26.7	19.2
0.5	T♀ x T♂	50	59.7±2.4	0.0
	T♀ x U♂	21	28.5±3.4	0.0
	U♀ x T♂	25	105.4±9.8	5.3
0.6	T♀ x T♂	40	58.8±2.7	0.0
	T♀ x U♂	27	27.1±2.6	0.0
	U♀ x T♂	27	46.0±9.4	0.0

[a]) Number of eggs per fecund female; mean ± standard error.

At 0.6 kGy dose of gamma radiation, both treated females mated to untreated males and untreated females mated to treated males produced no viable eggs.

Females of the bulb mite were clearly more radiosensitive than males, as shown by the differences in reproductive abilities of irradiated adults mated with untreated opposities. The sterilizing dose of gamma radiation was found to be 0.4-0.5 kGy for females, but for the males between 0.5 and 0.6 kGy. The females of the mold mite, Tyrophagus putrescentiae (Schrank), are also more sensitive to sterilizing action of the ionizing radiation than the males (Ignatowicz, 1986).

DISCUSSION and CONCLUSIONS

Our results show that control of the bulb mite, R. echinopus, infesting postharvest agricultural products is possible with relatively low doses of radiation. At as low dose as 0.25 kGy, (a) 0-2-day-old eggs do not hatch; (b) sterile adult mites develop from irradiated older eggs;sex ratio of these adults is male-biased; (c) mites emerged from treated deutonymphs laid a few eggs which all were sterile; (d) fecundity of mites irradiated as adults is much lower (by 87%) than of the controls; (e) larvae occasionally hatched from eggs produced by irradiated adults (egg hatchability about 0.2%).

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LA STERILISATION AUX RAYONS GAMMA DE L'ACARIEN DES BULBES RHIZOGLYPHUS ECHINOPUS (F. et R.) (ACARIDA : ACARIDAE)

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RESUME

L'âge des oeufs de l'acarien des bulbes, *Rhizoglyphus echinopus* (F. et R.) au moment de l'irradiation et la dose d'irradiation ont eu un effet important sur leur faculté d'éclosion. Une grande partie des oeufs les plus âgés se sont développés jusqu'au stade adulte. Cependant, le rapport entre les sexes de ces adultes était fortement en faveur des mâles.

La fertilité des acariens issus des deutonymphes irradiées a été fortement réduite. Cette réduction allait de 99 à 100 % lorsque la deutonymphe inerte était irradiée à une dose de 0,2 kGy, ou plus. La viabilité des oeufs pondus par les acariens issus des deutonymphes traitées s'est avérée très basse. A 0,1 kGy, environ 37 % des oeufs étaient morts mais, à 0,2 kGy, on a constaté 86 % de mortalité chez ces mêmes oeufs.

Les rayons gamma ont grandement affecté la fécondité de l'acarien des bulbes, lorsque les adultes ont été soumis à une dose de 0,1 kGy, ou plus. Les acariens adultes irradiés ont pondu plus longtemps que les acariens provenant de deutonymphes irradiées. Les femelles en général se sont montrées nettement plus radio-sensibles que les mâles : la dose de stérilisation s'est avérée être de 0,4-0,5 kGy pour les femelles, mais allait de 0,5 à 0,6 kGy pour les mâles.