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CORN GRAIN DISINFESTATION BY GAMMA RADIATION AND INSECTICIDE APPLICATION[1]

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This study was conducted to determine the effects of gamma irradiation from a Cobalt-60 source and insecticide treatment of sack containers in the preservation of corn grain against stored-product pests.

Irradiation of corn grain with 130 Kr. at about 2 Kr/hr resulted in significantly lower percentage (44%) of damaged kernels than in the control (70%) or irradiation at lower dosages of 10, 30 or 60 Kr.

Malathion-impregnated sacks and the irradiation of corn grain for 130 Kr or a combination of both were significantly effective in protecting the seeds against greater insect damage. Treatment of sacks with DDT did not reduce the damage to corn. A combination of irradiation and malathion-impregnated sacks gave the best protection to stored corn.

Insect destruction of food and food products such as stored grain and processed foodstuffs is one on the major problems in the Philippines. Labadan and Viado (1959) estimated that in corn alone, at least 5% of grain is lost to insect pests within a storage period of three months, and for a 6-month period, the loss increases to about 17% by weight. By this time about 75% of the kernel are already damaged by insects. From the annual corn production of 1,312 million kilos, it was estimated that about 65 million kilos valued at ₱13,700,000 are lost during the first three months of storage (1965 statistics). This amount of grain lost to insects could easily fill about 9% of the country's needs. Saving these grains will greatly contribute to the economy and food supply of the country.

The pests attack the corn by boring holes into the grain, consuming the contents and, in some cases, leaving only the outer covering thus rendering the grain unfit even for animal feed.

Many measures are being utilized in controlling these pests, the most common being the use of insecticides. The use of DDT-impregnated sacks was reported to give good protection against storage insects (Parkin 1948; Viado and Labadan 1958; Bandong and Banaag 1961). The use of malathion as direct treatment for corn grains was also reported (Sanchez and Calora 1966).

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Unfortunately, chemical control measures have not proven to be very effective and satisfactory. One big objection to the use of chemical insecticides is their highly toxic residues on treated grains. Also, it is often difficult to attain complete penetration thus resulting in the survival of part of the insect population.

Recently, the use of ionizing radiation have been shown to be an effective tool for insect pest control which can supplement or replace chemical control measures. Researches along this line have been directed toward the determination of the effects of gamma radiation on various developmental stages (Cornwell 1959; Cornwell 1966) and its lethal and sterilizing effects on the insects infesting cereal commodities (Cornwell *et. al.* 1957; Tilton *et. al.* 1966).

Studies on the effect of gamma radiation on the adults of rice weevil, *Sitophilus oryzae* L. and the rust-red flour weevil, *Tribolium castaneum* Herbst. were conducted at the Center in 1962 (Viado and Manoto 1963). Results of the study showed that 100% of the *Sitophilus* and *Tribolium* adults were killed at 40 and 60 Kr, respectively, thirty days after irradiation using a dose rate of 2,340 r/hr. Of the two species studied, *S. oryzae* appeared to be more susceptible to gamma radiation than *T. castaneum.*

This project was initiated with the following objectives:

1. To compare irradiation and insecticide application for effectiveness in controlling storage insects of corn.
2. To determine the dosage necessary for commercial application of gamma radiation.

MATERIALS AND METHODS

Irradiation work. Irradiation was carried out in a 430-curie Cobalt-60 facility of the Philippine Atomic Research Center. The source had an original strength of 630 curies when it started operation on May, 1963. The dosage levels used were as follows: 0, 10, 30, 60 and 130 Kr.[3] About 4 kilograms of corn grains were placed in small gunny sacks (26 x 48 cm) which were then tightly tied with abaca twine.

Irradiation was done at a distance of approximately 9 cm from the source (Fig. 1). Dosimetry (Fricke) using ferrous ammonium solution was done simultaneously with irradiation.

Insecticide. The insecticides used were DDT (75% W. P.) and malathion (57% E. C.). The gunny sacks used in the experiment were dipped in either 1% DDT or 1.25% malathion solution to allow thorough wetting and then air-dried before being used.

[3] 1 Kr = 1000 r. One roentgen unit, or r unit is that quantity of X or gamma radiation which corresponds to the absorption of 83.3 ergs of energy per g of air.

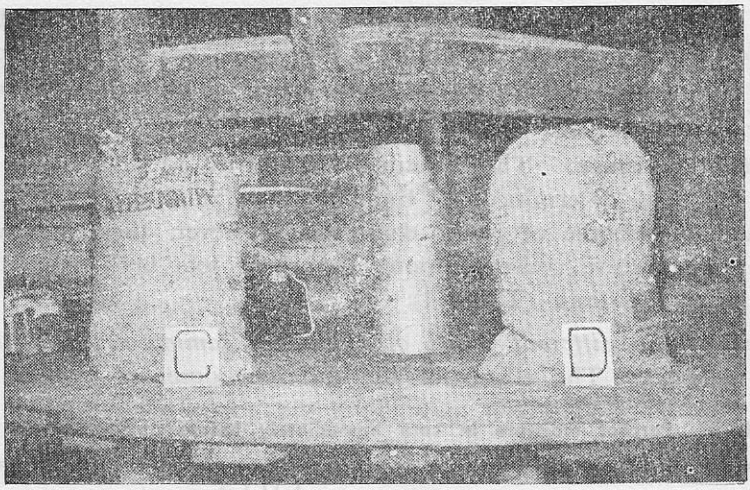

Fig. 1. Two small sacks of corn being exposed to a Cobalt-60 source.

Post-irradiation treatment. After irradiation, the corn grains were transferred to either treated or untreated sacks. The different treatments were randomly distributed and apart from each other. The treatments were replicated four times. The temperature at the storage room for the duration of the tests ranged from 80-89 F and the relative humidity 45-53%.

Moisture determination. The moisture content of the corn grains was determined by the oven method. Thelco Precision Model 16 oven was used for drying.

Collection of data. Counts on damaged corn grains were made before and immediately after treatment at one-month intervals thereafter until the sixth month. Two trials of 100 corn grains were taken randomly from each treatment. The count of damaged corn grains were first converted to percentages of two trials were determined. Different species of the stored-product pests were collected and identified. The experiment started on November 16, 1966 using the following treatments:

1 — no treatment, control
2 — sack treated with DDT
3 — sack treated with malathion
4 — irradiated with 130 Kr
5 — sack treated with DDT and irradiated with 130 Kr
6 — sack treated with malathion and irradiated with 130 Kr.

For analyses of variance all percentages were transformed into angles. LSD value in angles were reconverted into percentages.

RESULTS AND DISCUSSIONS

Insect pests observed. The most injurious stored-product pests which were found in great numbers were the flour beetle [*Tribolium castaneum*

Herbst], the rice weevil [*Sitophilus oryzae* (L.)] and the Indian meal moth [*Plodia interpunctella* (Hubn)]. The other less numerous pests were the lesser grain borer [*Rhyzopertha dominica* (F.)] and the saw-tooth grain weevil [*Oryzaephilus surinamensis* (L.)].

Effect of moisture. The amount of moisture in corn grain in three different lots was determined to find out any relation between moisture content and the degree of insect damage. However, there was very little difference in moisture content among the three lots both immediately before and after the tests (Table 1).

Effects of the different levels of Cobalt-60 gamma rays on the degree of insect damage. The effects of the different doses of gamma radiation

TABLE 1. **Percent moisture in corn immediately before and after the tests.**

	LOTS			
	I	II	III	Average
Before	12.27	12.14	11.80	12.07
After	11.91	11.76	11.59	11.75

are summarized in Table 2. The values are expressed as cumulative increase in per cent of damaged kernels after a specified number of months. The initial or pretreatment percentage damage was taken to determine if there has been an increase in the percentage of damaged kernel although only about three days at most have elapsed before the second observation was made. Column 3 of Table 2 was used as the base value for the first month.

It is very obvious from the results that the highest dose, 130 Kr, was effective in reducing the increase in damage by the stored-product pests from the second until the sixth month (Fig. 2). There was a delay in effect, that is, the decrease in damage was only found significant during the second and third months. This can be due to variation in susceptibility of the different developmental stages of the pests or differences in radiosensitivity of the various insect species. It is possible that only the immature stages, the egg, larva and pupa died soon after irradiation or during the first month and that the adults continued to feed and caused damage to kernels until they died during the second month. These results agree with those obtained by many workers who have shown that eggs, larvae and pupae are considerably more susceptible to radiation damage than the adults (Cogburn *et. al.* 1966; Tilton *et. al.* 1966) and that radiosensitivity varies with species.

The doses lower than 130 Kr were slower and less efficient in killing the adults of the pests. Unlike in the 130 Kr treatment group, there

TABLE 2. **Mean percentage damaged kernels using different doses of gamma radiation**

DOSE (Kr)	Initial % damage	% Damage immediately after treatment	PER CENT DAMAGED KERNELS AFTER SPECIFIED NUMBER OF MONTHS											
			1		2		3		4		5		6	
			A	B	A	B	A	B	A	B	A	B	A	B
0	11.4	11.8	12.0	23.0	13.9	36.9	13.0	49.9	4.3	54.2	7.9	62.1	7.5	69.6
10	13.0	12.5	11.9	24.4	13.2	37.6	5.3	42.9	5.3	48.2	7.7	55.9	13.1	69.0
30	10.7	9.5	12.6	22.1	11.5	33.6	7.5	41.1*	10.5	51.6	2.3	53.9	13.2	67.1
60	9.8	10.8	12.6	23.4	11.2	34.6	6.6	41.2*	7.3	48.5	10.4	58.9	7.8	66.7
130	12.1	12.0	12.7	24.7	2.3	27.0**	—1.4	25.6**	3.5	29.1**	7.7	36.8**	6.9	43.7**
LSD														
0.05	NS	NS		NS		6.4		8.0		7.3		7.0		7.3
0.01	NS	NS		NS		8.9		11.2		10.3		9.9		10.3

A — increments in % damaged kernels between months
B — cumulative increase in % damaged kernels
NS — not significant
** — significant at 1% level
* — significant at 5% level

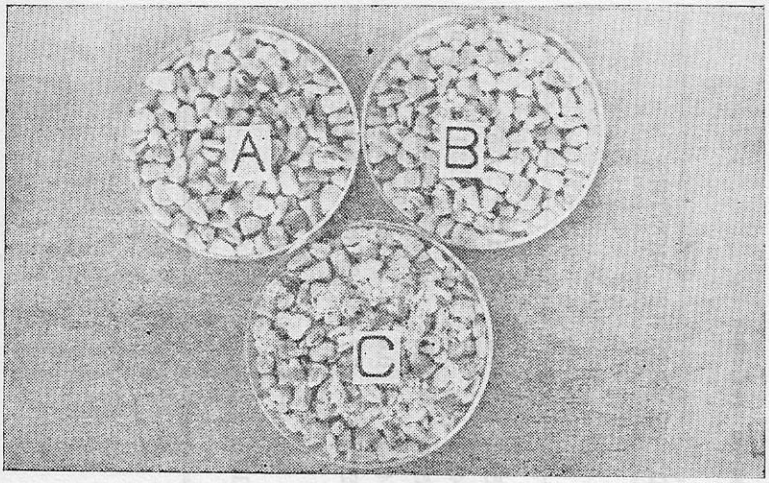

Fig. 2. Samples of irradiated corn kernels 6 months after treatment. *A.* — irradiated with 130 Kr and placed in malathion-treated sack; *B.* — irradiated with 60 Kr and placed in malathion-treated sack; *C.* — untreated control.

were still adults living during the third month to cause some damage which was about half of that in the control group.

During the fourth month there seemed to be two spurious or erratic observations. The increment of damage for the control group was too low (4.3%) while that for the 30 Kr dose was too high (10.5%). The erratic trend in damage increment for the 30 Kr level carried through the fifth (2.3%, which is too low) and sixth (13.2%, which is too high) months. Likewise, the damage increment for the 10 Kr dose was too high (13.1%) during the sixth month.

In spite of the somewhat large sampling error, however, one can still have a reasonable explanation for the data in Table 2. Some of the population in the 10, 30, and 60 Kr treatment groups were actually progeny of the survivors from irradiated treatment. Similarly, the population of the adult pests during the fourth month in the 130 Kr treatment was composed partly of progeny of adults which survived up to the last few days of the second month. The population build-up, as inferred from the rise of the damage increments, during the fourth, to sixth months was partly due to the natural increase in population. The similarity, however, of the damage increments of the control with that of the 130-Kr treatment during the sixth month requires explanation. It has to be postulated that the natural increase of population from the survivors in the 130 Kr treatment was augmented by re-infestation from the control.

Based on the preceding statements, it was found that the degree of effectiveness of gamma radiation in reducing insect damage was a function of the dose received by the corn grains. The greater the dose, in this case 130 Kr, the greater the effectivity in reducing the increase in

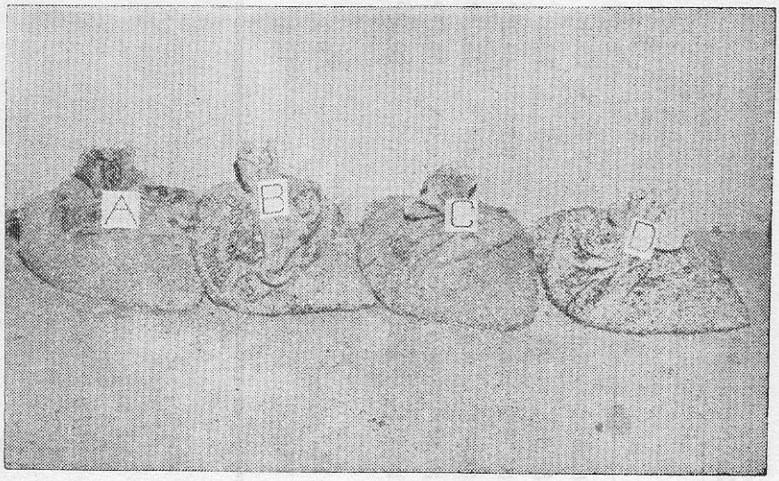

Fig. 3. Small sacks of corn 6 months after treatment. *A.* — corn irradiated with 130 Kr; *B.* — corn irradiated with 130 Kr and placed in DDT-treated sack; *C.* — untreated control; *D.* — corn irradiated with 130 Kr and placed in malathion-treated sack. Note that the dead stored-product pests are still attached to the sack.

damage by stored-product pests in corn grain. This dose was considered high as compared with 64 Kr which was found completely lethal to rice weevil, flour beetle, lesser grain borer, and 5 other storage pests in less than three weeks (Hassett and Jenkins 1952). The 130 Kr dose was delivered to the naked adults at a dose rate of 165 Kr/hr. In a much more recent work (Watters and MacQueen 1967), 51 Kr delivered at a dose rate of 94 Kr/hr was found completely lethal to 4 species of stored-product insects within about three weeks after irradiation. Since in this experiment corn was treated in bulk, the grain itself could have served as shield for the pests inside the kernels. Hence, a much higher dose was needed before considerable reduction in damage was observed. In addition, since the dose rate used in this study was only about 2 Kr/hr, it took a longer exposure period of 63 hours before the total dose of 130 Kr was obtained and about 2 months had to elapse after treatment before reduction in damage was noticed.

Effectiveness of the different treatments in preserving corn against insect damage. Table 3 shows a summary of the effects of the different treatments in reducing the rate of increase of insect damage in corn. As in the previous experiment, no significant differences were observed among the treatments at the end of the first month. However, there was a big drop in the increment of damage during the second month for treatments 4, 5 and 6. This was the same effect of 130 Kr of Co-60 gamma rays observed in the first experiment. During the third month there was no damage increment for treatments 4 and 6, almost none in treatment 5. Re-infestation seemed to have occurred during the fourth month in treat-

TABLE 3. **Mean percentage damaged kernel in different treatments involving 130 Kr. of Co-60 gamma rays on the kernel and/or insecticide impregnation of the sack container.**

TREATMENT[1]	Initial % damage	Damage immediately after treatment %	PER CENT DAMAGED KERNELS AFTER SPECIFIED NUMBER OF MONTHS[2]											
			1		2		3		4		5		6	
			A	B	A	B	A	B	A	B	A	B	A	B
1	9.8	10.4	13.7	24.1	17.8	41.9	17.9	59.8	2.7	62.5	3.6	66.1	7.7	73.8
2	10.8	11.6	13.7	25.3	14.2	39.5	14.0	53.5	4.5	58.0	9.1	67.1	5.3	72.4
3	10.4	10.0	18.4	29.4	11.8	41.2	6.0	35.2**	—2.1	33.1**	6.9	40.0**	9.2	49.2**
4	9.8	9.7	18.8	28.5	2.3	30.8**	—3.4	27.4**	5.0	32.4**	8.4	40.8**	4.4	45.2**
5	11.4	11.8	17.4	29.2	2.3	31.5**	1.5	33.0**	—1.4	31.6**	14.5	46.1**	6.0	52.1**
6	10.0	9.9	15.0	24.9	2.9	27.8**	—3.9	23.9**	—0.1	23.8**	2.3	26.1**	1.5	29.6**
LSD														
0.05	NS[3]	NS		NS		7.4		9.7		11.3		6.9		9.3
0.01	NS	NS		NS		10.3		13.4		15.6		9.6		12.8

** — significant at 1% level

[1] — Treatment:
1 = control
2 = DDT
3 = Malathion
4 = 130 Kr
5 = 130 Kr + DDT
6 = 130 Kr + malathion

[2] — A = increments in per cent damaged kernels between months; B = cumulative increase in % damaged kernel

[3] — NS = not significant

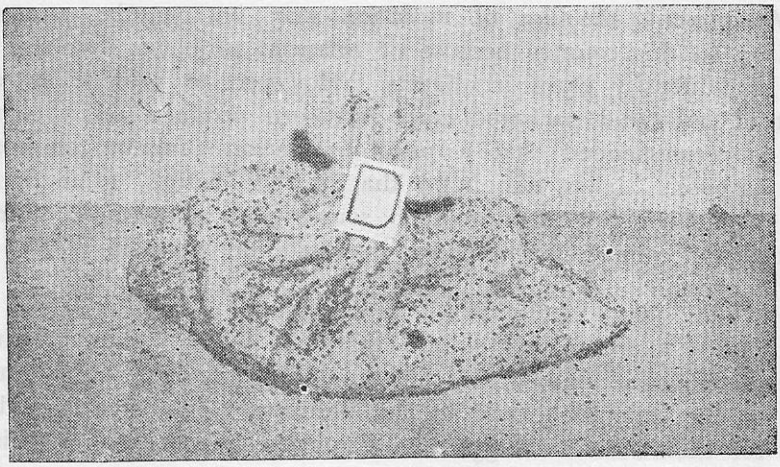

Fig. 4. A close-up of corn irradiated with 130 Kr and placed in malathion-treated sack. Note the dead insects still attached to the sack.

ment 4; during the fifth month in treatment 5 and 6. It appeared that malathion was more effective in delaying and reducing re-infestation than DDT. Thus, the combination treatment of radiation and malathion (Treatment 6) had the least cumulative damage after the six months of storage (29.6%). The fumes of malathion must have killed some of the insect pests as shown by the low cumulative damage in treatment 3 (49.2%). The difference between the cumulative damage after six months in treatment 4 (45.2%) and 6 (29.6%), therefore, was due to both toxic effects of malathion and its ability to ward off re-infestation (see Fig. 3). Results of the experiment conducted at the U.P. College of Agriculture (Sanchez and Calora 1966) showed that direct treatment of corn grains with malathion coupled with the use of paper-lined gunny sacks offered good protection against rice weevil attack for at least 9 months.

In this study DDT did not seem to give any protective effect to the stored corn grain. This is in contrast with the results reported by Bandong and Banaag (1961) and Viado and Labadan (1958). The apparent discrepancy in results might have been due to the fact that in the present study the corn grains were already infested with weevils before they were placed in DDT-impregnated sacks.

RECOMMENDATION

The present findings have important implications in radiation disinfestation of grain in the Philippines. The results showed that insect damage to corn grain in storage can be reduced with the use of 130 Kr gamma radiation from a Cobalt-60 source. In addition, the use of malathion-impregnated sack after exposure to 130 Kr dose was very effective in protecting the kernels against the depredation of stored-product

pests. At present, the use of radiation may not yet be recommended commercially in this country because of financial problems involved in putting up high-intensity grain irradiators. However, to provide an effective treatment of bulk and packaged corn and corn products on a commercial basis, it is recommended that a pilot irradiation program be conducted for this purpose. It is our hope that in the future, grain irradiators provided with high intensity cobalt-60 source and a conveyor system will be obtained for commercial radiation disinfestation program.

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