Marketing Research Report No. 531

The Effects of Cathode-Ray Irradiation on the Rice Weevil in Wheat

Market Quality Research Division
Agricultural Marketing Service
U.S. DEPARTMENT OF AGRICULTURE

This report contains some results of a cooperative study conducted in 1954 by the Agricultural Research Service, the Agricultural Marketing Service, U.S. Department of Agriculture, and the General Electric Company. The information has earlier been made available in somewhat fragmentary form within the Department of Agriculture, but has not been given general distribution. General publication has been delayed because of personnel shifts, both within the Department and the cooperating company. Although this work was done some time ago, the results are still valid. The equipment and techniques have not changed.

The equipment for generation of the cathode rays was furnished by the General Electric Company, Milwaukee, Wis., and technical assistance was given by Mr. R. F. Holste, manager of the Industrial Products Division, Mr. H. Schreiber, Jr., and Mr. Joseph Rantfl. Dr. V. A. Johnson of the Agronomy Department of the University of Nebraska supplied the wheat used in the germination tests.

This report is one of a group presenting results of studies of the use of physical and mechanical means for controlling insects that attack stored products.

Reports in this group are a part of a broad program of marketing research being conducted to reduce the cost of marketing farm products, including the cost of preventing insect infestation in stored grain.

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THE EFFECTS OF CATHODE-RAY IRRADIATION ON THE RICE WEEVIL IN WHEAT

by N. M. Dennis, L. H. Soderholm, and H. H. Walkden[1]

SUMMARY

High-voltage cathode rays were used to study their effect on rice weevils and on wheat seed. Exposures of 10,000 to 200,000 r.e.p. (roentgens equivalent physical) were employed. Adult rice weevils irradiated at 20,000 and 30,000 r.e.p. died within a week without reproducing. When exposed to 10,000 r.e.p., they lived for 7 or 8 weeks and nearly all of them failed to reproduce. The egg stage failed to develop after exposure to 10,000 r.e.p. However, this dosage did not control infestations in wheat. Wheat seeds germinated after doses of up to 200,000 r.e.p., but the embryonic plants did not continue to develop if they received doses of 40,000 r.e.p. or more.

BACKGROUND AND PURPOSE OF THE WORK

The effective use of radiant energy for the control of insects infesting stored wheat has not advanced beyond the experimental stage. Laboratory tests with high-frequency fields to control rice weevils (*Sitophilus oryzae* (L.)) in wheat have been conducted, and the recent availability of equipment for the generation of cathode rays suggested a consideration of this type of radiation for the same purpose.

Very few investigations have been undertaken to determine the value of high-voltage cathode-ray irradiation in controlling stored-grain insects. Yeomans (11)[2] has reported the results of experiments with a 3-million-volt capacitron generator. In these experiments, larvae of the confused flour beetle in an 8-mm. thickness of flour were killed when exposed to one impulse on each side at 310,000 r.e.p. (roentgens equivalent physical).

V. H. Baker, O. Taboada, and D. E. Wiant (1) conducted experiments on the granary weevil and the confused flour beetle, using a 2-million-volt Van de Graaff generator. They report that an electron dose of 10,000 r.e.p. will sterilize flour beetle and granary weevil eggs and prevent the adults from reproducing. Dosages of 50,000 r.e.p. were lethal to 100 percent of adult flour beetles immediately after treatment, and irradiations at 25,000 r.e.p. were lethal to 100 percent of the adult weevils.

Wheat irradiated at 50,000 r.e.p. produced a satisfactory loaf of whole wheat bread, from a physical standpoint; however, a slight change in the taste of the treated bread was detected.

Dosages exceeding 10,000 r.e.p. were detrimental to wheat seed. Wheat irradiated at 50,000 r.e.p. germinated but did not grow.

Coolidge and Moore (4); Trump and Van de Graaff (9); Urbain (10); Hassett and Jenkins (7); and Bushland and Hopkins (2) have all reported on the biological effects of X-rays, cathode rays, or gamma radiation.

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[1] At the time this work was done, Mr. Dennis was stationed at the Manhattan, Kans., Laboratory of the Stored-Product Insects Branch, Agricultural Marketing Service, U.S. Department Agriculture. He is now located at the Savannah, Ga., laboratory.

Mr. Soderholm was stationed at Lincoln, Nebr., a field station of the Agricultural Engineering Research Division, Agricultural Research Service, U.S. Department of Agriculture.

Mr. Walkden was formerly stationed at the Manhattan, Kans., laboratory.

[2] Underscored figures in parentheses refer to Literature Cited, p.14.

The effect of cathode rays on the germination and early growth of wheat was undertaken as part of a project for the investigation of the application of radio-frequency heating and other forms of electromagnetic radiation to the preservation and processing of agricultural commodities.

Although a number of investigations have been conducted in past years to determine the effects of various types of electromagnetic radiation on living organisms, much of the experimental work in that part of the frequency spectrum above that of visible and ultraviolet light has been study of the effects of X-rays. Interest has centered largely on the effect of this type of radiation on the production of chromosome aberrations and the consequent effect upon inheritance.

Experimental work has been performed with other types of radiation in recent years as new sources have become available, but only a limited amount of information is recorded on the effect of cathode rays on plants. The terms "cathode rays," "accelerated electrons," "rapid electrons," and "negative beta particles" have all been used to designate high-energy electrons. Of these, the first three terms are usually applied to electrons that have been artificially accelerated to high velocities by high-voltage fields, while the fourth term is generally used for electrons emitted in nuclear reactions.

The ultimate penetration of cathode rays is approximately 5 mm. per million volts acceleration for material of unit density and varies inversely with density for most materials of low atomic weight. The disadvantage of this rather limited penetration is offset to a large extent by a high efficiency in the production of cathode rays. Trump and Van de Graaff (9) and Dunn, et al., (6) found that cathode rays could be used with several hundred times the efficiency of X-rays. The finding may be attributed to the low efficiency of production of X-rays and their limited concentration towards the target.

Differences in the effects between types of radiation have been reported in numerous references in the earlier literature. However, later workers, including Packard and Heilbrunn and Mazia, in Duggar (5) agree that the different types of radiation produce similar effects when comparable energy inputs per unit of time and per unit of volume are absorbed, indicating an advantage of cathode rays in some applications.

The major objective of the first test was to determine the effects of cathode-ray irradiation on rice weevils infesting wheat. The initial series of tests, using an electron-beam unit, was preliminary in nature. It was expected that the results would point the way to more intensive experiments and a practical method of insect control in stored wheat. Further research may lead to this end.

MATERIALS AND APPARATUS

The Cathode-Ray Unit

The cathode-ray equipment used for these experiments consisted of a General Electric Resotron[3] 1,000 unit, which is nominally rated at 1,000 KVP (kilovolts-peak), 3-milliampere (ma.), for the generation of X-rays (fig. 1). This type of apparatus employs a hot-cathode, multisection tube in which the accelerating potential is obtained from a resonance transformer supplied from a 180-cycle synchronous motor-driven alternator as described by Charlton, and others (3). This unit was modified for the production of cathode rays by replacing the tungsten target of the X-ray tube with a thin stainless-steel window to allow the accelerated electrons to emerge into the air. The output from this equipment therefore consists of high-energy electrons of a sine wave energy distribution delivered during the rectifying half cycle. This unit has a current estimated market price

[3] Proprietary and brand names are used only for identification of the equipment that was used in the tests, and their use should not be construed as an endorsement or to exclude other equipment that would also be suitable.

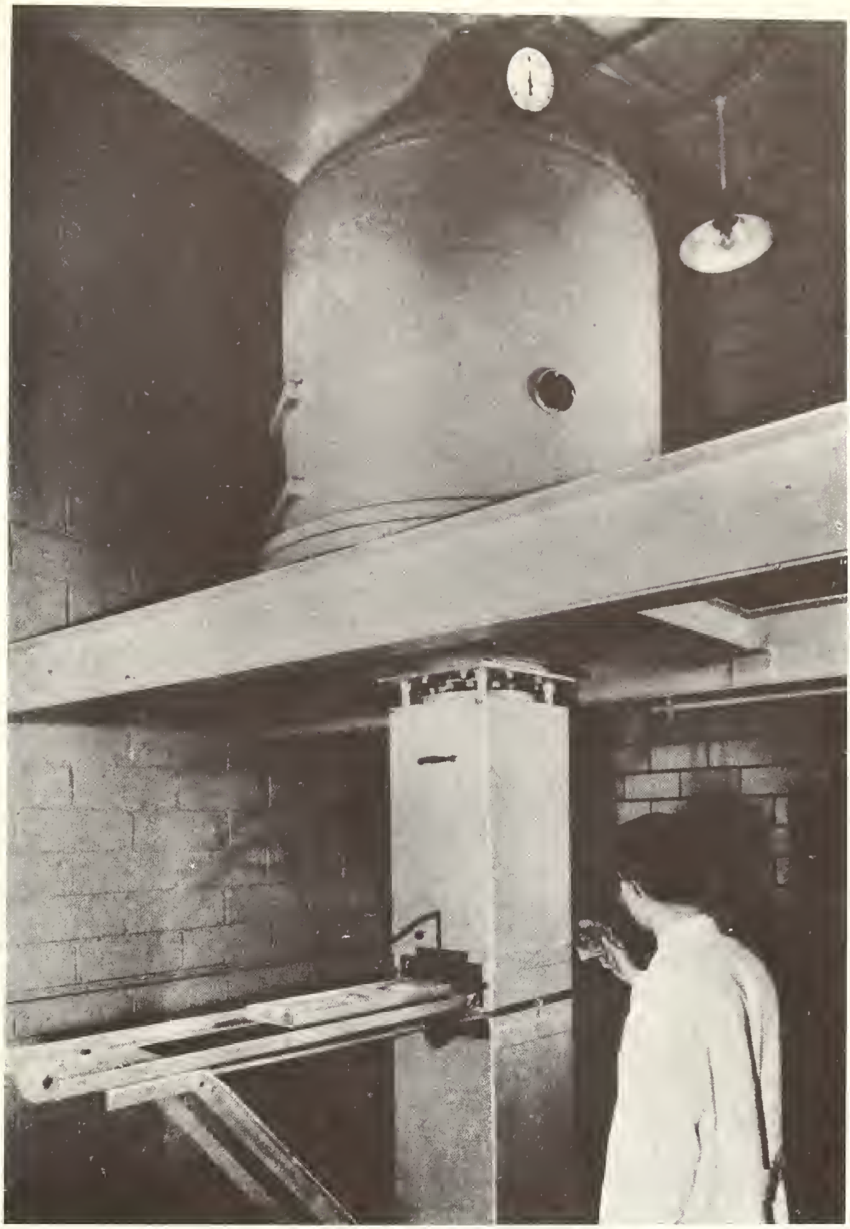

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Figure 1.--Cathode-ray unit installed in laboratory for experimental purposes.

of $60,000. It is compact and portable, and it can be operated in all positions. Other machines that generate cathode rays are manufactured by various companies.

Levels of Radiation

This apparatus was operated at 800 KVP for the work reported. The applied dosages were calculated from calibration data supplied by the cooperator. The levels of radiation were determined from this calibration data, which employed ionization chamber measurements of the intensity and energy distribution of the 800-KVP electron beam. The treatment intensities stated are average values obtained from these data for samples irradiated at a distance of 10 cm. from the stainless steel window. The energy distribution for these conditions is as shown in figure 2, indicating a maximum deviation of no greater than approximately 12 percent at the edge of the beam from the average value at the center of the beam. Three replications were made at each level of radiation for exposures of 10,000, 20,000, 30,000, 40,000, 50,000, 60,000, 75,000, 100,000, 150,000, and 200,000 r.e.p., corresponding to a beam-out current of 0.75, 1.5, 2.25, 3.0, 3.75, 4.5, 5.63, 7.5, 11.25, and 15 microamperes, respectively, at 800 KVP.

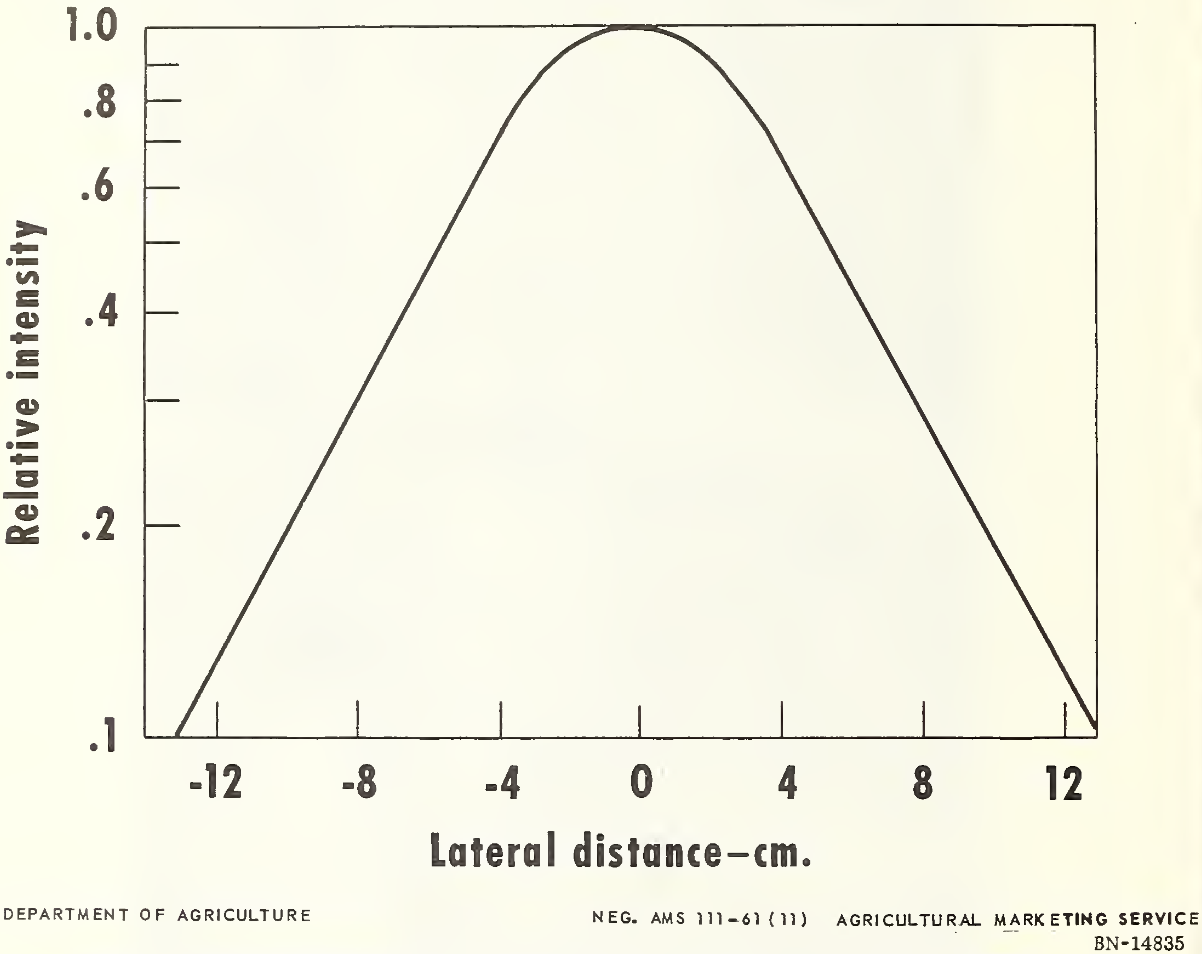

Figure 2.--Energy distribution of 800-KVP electron beam at a distance of 10 cm. from the window.

Cost of Operation

Precise figures on the cost of operation of cathode-ray equipment for the destruction of insects in wheat must await complete data as to the exact exposure required. However, an estimate may be made from consideration of these factors:

The roentgen unit, which is a measure of the energy absorbed, is equivalent to 83.8 ergs per gram of air or 8.4 joules of energy per gram of material for an absorption of 1 million roentgens. Eight and four-tenths joules per gram may be more conveniently expressed as 1.06 watts of beam power required for the absorption of 1 million roentgens in 1 pound of material per hour.

If an assumed dosage of 100,000 roentgens is required, 0.106 w.-hr. (watt-hour) is necessary for the treatment of 1 pound per hour, and 60 x 0.106 w.-hr., or 6.36 w.-hr., are necessary to treat 1 bushel per hour.

Making further assumptions of a conversion efficiency of electrical power to cathode-ray energy of 50 percent, and an energy cost of 2¢/kw.-hr., the treatment cost per bushel would be 6.36/1,000 x 2¢, which is equal to 0.013¢/bu. Thus, the energy cost is extremely low.

The larger part of the treatment cost will probably be for amortization and maintenance of the equipment.

The Test Insects

The test insects were reared in wheat at a constant temperature of 80° F. and 60-percent relative humidity.

As needed, 10-ml. samples were drawn from the cultures for exposure to cathode rays.

Culture No.:

(2) Wheat, moisture 14.75 percent, infested with adults for 2 days, contained egg stages.

(3) Wheat, moisture 12.55 percent, infested with adults for 2 days, contained egg stages.

(4) Wheat, moisture 14.60 percent, infested with adults for 7 days, contained egg and early larval stages.

(5) Wheat, moisture 14.70 percent, infested with adults for 7 days and incubated for 7 days, contained larval and pupal stages.

(6) Wheat, moisture 15.60 percent, infested with adults for 7 days and incubated for 14 days, contained larval, pupal, and adult stages.

(7) Wheat, moisture 16.40 percent, infested with adults for 7 days and incubated for 21 days, contained pupal and adult stages.

PROCEDURES

The samples from the cultures of infested wheat were irradiated in a single-kernel layer in aluminum-foil trays 3 1/2 x 2 1/4 x 1/4 inches (fig. 3). The aluminum foil was used to utilize the backscatter from the cathode rays and minimize X-ray radiation. In addition, adult specimens were bagged in heat-sealed plastic bags 2 1/2 x 2 1/2 x 0.0015 inches thick to confine the insects' movements within the limits of the cathode-ray field.

Prepared samples of 10 ml. of infested wheat and 10 adult rice weevils as described were lined up in single file on a sample holder and passed under the window of the cathode-ray unit on a conveyor. The speed of the conveyor was fixed, and therefore the dosage given was controlled by variation of the beam-out current of the cathode-ray unit. The kernels were placed one layer deep in aluminum-foil trays, 3 1/2 x 2 1/4 x 1/4 inches, and passed under the window of the cathode-ray machine on a conveyor at a fixed speed of 14 inches per minute, which gave an exposure of about three-fourths of a minute. Irradiation was from one side only. Exposures of 10,000, 20,000, 30,000, 40,000, 50,000, 60,000, 75,000, 100,000, 150,000, and 200,000 r.e.p. were given.

After the treatment at Milwaukee, Wis., each sample was numbered, placed in an insect-tight polystyrene box and flown back to Manhattan, Kans., for rearing and observation in an insect culture room under favorable rearing conditions. At the end of

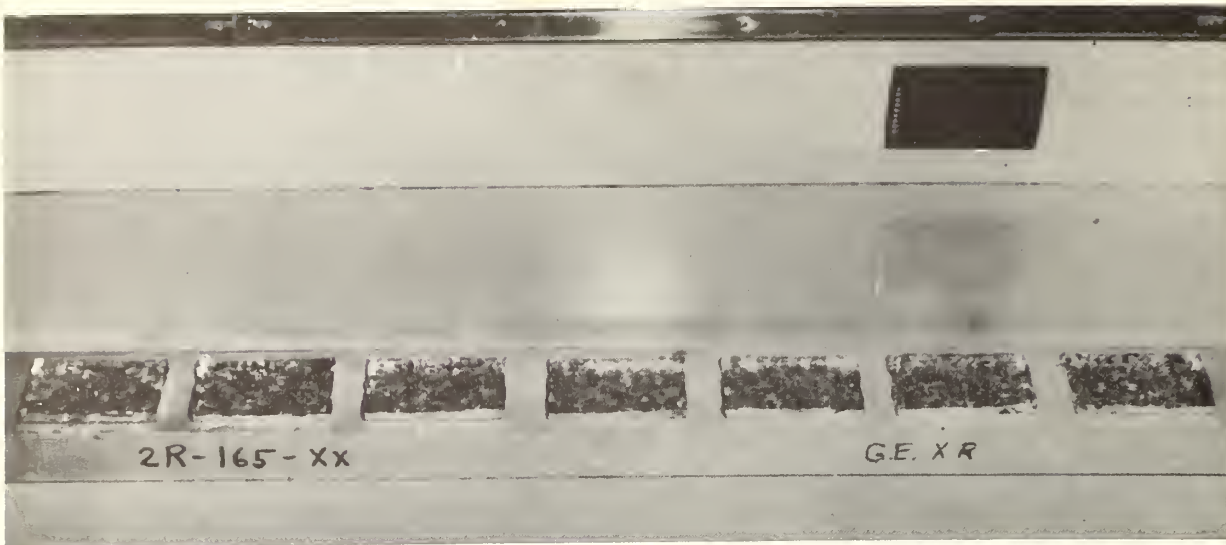

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Figure 3. --Samples in aluminum-foil trays on wooden train, ready for irradiation on conveyor.

each week for 6 weeks following treatment, these samples were screened, and the live and dead adult rice weevils were removed and placed in clean, uninfested wheat in glass vials. At the end of 5 months, all of the weekly samples were checked. The live and dead insects were counted if they were fewer than 100, and the number was estimated if more than 100. The condition of the wheat was observed and recorded.

RESULTS

Effects of Cathode Rays on the Adult Rice Weevil

The adult rice weevils required an exposure of 100,000 r.e.p. for the instant death of 4 replicates of 10 adult weevils sealed without wheat in plastic bags (table 1). It would be most desirable to cause immediate death with cathode-ray treatments for all insects infesting the wheat in order that the full advantages of the treatment might be realized. Since there is no residual protection, only one or more surviving fertile female insects could cause reinfestation in a short time.

TABLE 1.--Mortality of adult rice weevils exposed to cathode rays in heat-sealed 0.0015-inch plastic bags

Sample number	Exposure	Initial observation	Mortality of irradiated insects after interval of[1]--									
			1 week	2 weeks	3 weeks	4 weeks	5 weeks	6 weeks	7 weeks	8 weeks	9 weeks	10 weeks
	R.e.p.		Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
1.....	200,000	All dead	100	100	100	100	100	100	100	100	100	100
71.....	200,000	All dead	100	100	100	100	100	100	100	100	100	100
141.....	200,000	All dead	100	100	100	100	100	100	100	100	100	100
210.....	200,000	All dead	100	100	100	100	100	100	100	100	100	100
8.....	150,000	All dead	100	100	100	100	100	100	100	100	100	100
78.....	150,000	All dead	100	100	100	100	100	100	100	100	100	100
148.....	150,000	All dead	100	100	100	100	100	100	100	100	100	100
219.....	150,000	All dead	100	100	100	100	100	100	100	100	100	100

-Continued

TABLE 1.--Mortality of adult rice weevils exposed to cathode rays in heat-sealed 0.0015-inch plastic bags--continued

Sample number	Exposure	Initial obser-vation	Mortality of irradiated insects after interval of[1]--									
			1 week	2 weeks	3 weeks	4 weeks	5 weeks	6 weeks	7 weeks	8 weeks	9 weeks	10 weeks
	R.e.p.		Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
15.....	100,000	All dead	100	100	100	100	100	100	100	100	100	100
85.....	100,000	All dead	100	100	100	100	100	100	100	100	100	100
155.....	100,000	All dead	100	100	100	100	100	100	100	100	100	100
228.....	100,000	All dead	100	100	100	100	100	100	100	100	100	100
22.....	75,000	Inactive	100	100	100	100	100	100	100	100	100	100
92.....	75,000	Inactive	100	100	100	100	100	100	100	100	100	100
162.....	75,000	Inactive	100	100	100	100	100	100	100	100	100	100
237.....	75,000	Inactive	100	100	100	100	100	100	100	100	100	100
29.....	60,000	Injured	100	100	100	100	100	100	100	100	100	100
99.....	60,000	Injured	100	100	100	100	100	100	100	100	100	100
168.....	60,000	Injured	100	100	100	100	100	100	100	100	100	100
250.....	60,000	Injured	100	100	100	100	100	100	100	100	100	100
36.....	50,000	Crippled	100	100	100	100	100	100	100	100	100	100
106.....	50,000	Crippled	100	100	100	100	100	100	100	100	100	100
175.....	50,000	Crippled	100	100	100	100	100	100	100	100	100	100
259.....	50,000	Crippled	100	100	100	100	100	100	100	100	100	100
43.....	40,000	Crippled	100	100	100	100	100	100	100	100	100	100
113.....	40,000	Crippled	100	100	100	100	100	100	100	100	100	100
182.....	40,000	Crippled	100	100	100	100	100	100	100	100	100	100
268.....	40,000	Crippled	100	100	100	100	100	100	100	100	100	100
50.....	30,000	Active	40	100	100	100	100	100	100	100	100	100
120.....	30,000	Active	100	100	100	100	100	100	100	100	100	100
189.....	30,000	Active	100	100	100	100	100	100	100	100	100	100
277.....	30,000	Active	90	100	100	100	100	100	100	100	100	100
57[2]....	20,000	Active	80	90	90	90	90	90	90	(3)	--	--
127.....	20,000	Active	50	100	100	100	100	100	100	100	100	100
196.....	20,000	Active	90	100	100	100	100	100	100	100	100	100
286.....	20,000	Active	77	100	100	100	100	100	100	100	100	100
64.....	10,000	Active	30	30	30	30	30	30	(3)	--	--	--
134.....	10,000	Active	60	60	60	70	90	90	90	100	(4)	--
203.....	10,000	Active	33	44	44	44	78	89	100	(4)	--	--
295.....	10,000	Active	67	67	89	100	100	100	100	(4)	--	--
304.....	Check	Active	0	0	0	0	(3)	--	--	--	--	--
318.....	Check	Active	0	0	10	10	(3)	--	--	--	--	--
305.....	Check	Active	0	0	0	0	(3)	--	--	--	--	--
315.....	Check	Active	7	7	14	14	(3)	--	--	--	--	--

1 Insects were cultured in wheat under favorable conditions for 10 weeks after irradiation.
2 Insects blew off conveyor in treatment--disregard the data.
3 Insects emerged normally, and samples were destroyed.
4 Wheat showed damage from feeding of adults.

The adult rice weevils irradiated at 30,000 r.e.p. and 20,000 r.e.p. lived for only 1 week and did not reproduce (fig. 4). However, a very slight amount of feeding damage was observed.

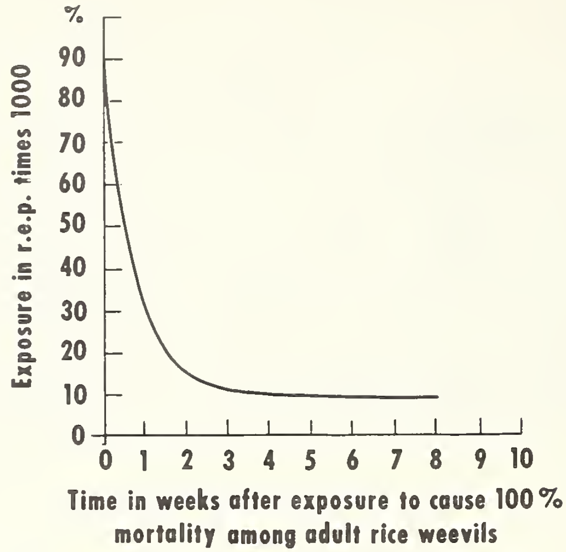

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Figure 4.--Cathode-ray dosage in r.e.p. vs. time to cause 100-percent mortality of 40 adult rice weevils treated in 4 lots in sealed plastic bags.

The adult rice weevils irradiated at 10,000 r.e.p. lived for 7 or 8 weeks after treatment and also failed to reproduce, with the exception of those in samples 64 and 295 (table 2). Some feeding damage in these samples was also observed.

It is not known whether the adults irradiated at 30,000, 20,000, and 10,000 r.e.p. were sterilized directly by the cathode-ray treatment or failed to infest the culture wheat due to other abnormal conditions resulting from the irradiation.

A series of four check samples showed low adult mortality the first 4 weeks, when cultured under the same conditions as the treated samples. Normal emergence of rice weevils in infested culture wheat continued after the first 4 weeks.

Figure 4 shows more clearly the effects of cathode-ray dosages in reducing the life span of adult weevils after treatment. Untreated control weevils lived for 6 to 8 months. As shown by the graph, 20,000 r.e.p. seems to be a critical point, based on the requirement of death within 2 weeks after exposure. Insecticides are generally considered ineffective if they fail to cause death to the insect within 2 weeks after treatment.

All of the adult insect samples were checked for mortality weekly for 10 weeks, then held under favorable culture conditions and checked again after 5 months to determine the number of live and dead rice weevil adults, to measure reproduction, and to determine the condition of the wheat in the sample. The results are given in table 2. The higher numbers of adults in three irradiated samples and all four check samples show that some reproduction took place during the 5 months' holding period. Sample 57, treated at 20,000 r.e.p., had 23 dead adult weevils, and the culture wheat was in only fair condition. The data from this sample cannot be considered because the insects blew off the conveyor during treatment. However, it can be seen that even with this uncertain dosage, death occurred sooner and there was less reinfestation of the sample than in the check samples 304, 318, 305, or 315. At the 10,000 r.e.p. dosage, samples 64 and 295 showed both live and dead adult rice weevils. However, these samples were less heavily infested than the check samples.

TABLE 2.--Mortality of treated adult rice weevils and the condition of the culture of wheat samples after 5 months

Exposure to cathode rays	Sample number	Adult rice weevils		Condition of wheat	Exposure to cathode rays	Sample number	Adult rice weevils		Condition of wheat
		Live	Dead				Live	Dead	
R.e.p.		No.	No.		R.e.p.		No.	No.	
200,000.....	1	0	10	Good	40,000.....	43	0	10	Good
	71	0	10	Good		113	0	10	Good
	141	0	10	Good		182	0	10	Good
	210	0	10	Good		268	0	10	Good
150,000.....	8	0	10	Good	30,000.....	50	0	10	Good
	78	0	10	Good		120	0	10	Good
	148	0	10	Good		189	0	10	Good
	219	0	10	Good		277	0	10	Good
100,000	15	0	10	Good	20,000.....	57	0	23	Fair
	85	0	10	Good		127	0	10	Good
	155	0	10	Good		196	0	10	Good
	228	0	10	Good		286	0	10	Good
75,000	22	0	10	Good	10,000	64	50	10	Destroyed
	92	0	10	Good		134	0	10	Fair
	162	0	10	Good		203	0	10	Good
	237	0	10	Good		295	6	11	Fair
60,000	29	0	10	Good	Check......	304	30	150	Destroyed
	99	0	10	Good		318	20	200	Destroyed
	168	0	10	Good		305	100	50	Destroyed
	250	0	10	Good		315	100	50	Destroyed
50,000	36	0	10	Good					
	106	0	10	Good					
	175	0	10	Good					
	259	0	10	Good					

It might be assumed that increased dosages would be required to produce comparable results when the adult insects are treated in the grain and are partly shielded from the radiation by the kernels.

As shown in table 3, the egg stage of the rice weevil was the stage most susceptible to the cathode-ray treatments. A dosage of 10,000 r.e.p., the lowest dosage used in the experiments, prevented the eggs from developing.

More experiments should be conducted to determine whether the egg is sterilized or if the weevil hatches and fails to reach maturity.

No difference between the 14.75-percent-moisture wheat and the 12.55-percent-moisture wheat could be detected. One sample in each culture group, 190 and 150, showed incomplete control. This could be accounted for either by an error in treatment, or by the inability of the cathode rays to penetrate, since we were working very close to the limits of penetration.

A dosage of 10,000 r.e.p. did not control the infestation in wheat from cultures 4, egg and early larval stage; 5, larval and pupal stages; 6, larval, pupal, and adult stages; and 7, pupal and adult stages of the rice weevil. In numerous instances the pupae transformed to adults, but the adults were unable to make their way out of the kernels before death overtook them (fig. 5).

TABLE 3.--Number of adult rice weevils removed from irradiated 10-ml. cultures of wheat a given number of weeks after irradiation at specified r.e.p. dosage of cathode rays their survival for 5 months, and the condition of the wheat in the new cultures on which the weevils were confined. Dosages of 200,000, 150,000, 100,000, 75,000, 60,000, 50,000, 40,000, 30,000, 20,000, and 10,000 r.e.p. were replicated 4 times with each culture; however, exposures or replicates not listed yielded no adult weevils

Cathode-ray dosage and sample number	First week			Second week			Third week			Fourth week			Fifth week			Sixth week		
	Live	Dead	Condition of wheat	Live	Dead	Condition of wheat	Live	Dead	Condition of wheat	Live	Dead	Condition of wheat	Live	Dead	Condition of wheat	Live	Dead	Condition of wheat
Culture No. 2: Wheat at 14.75 percent moisture content containing weevil eggs																		
	No.	No.		No.	No.		No.	No.		No.	No.		No.	No.		No.	No.	
30,000 r.e.p.:																		
190	0	0	Good	0	0	Good	0	0	Good	0	0	Good	0	0	Good	50	0	Poor
None:																		
Check	0	0	Good	0	0	Good	0	0	Good	0	0	Good	71	4	Destroyed	55	10	Destroyed
Culture No. 3: Wheat at 12.55 percent moisture content containing weevil eggs																		
150,000 r.e.p.:																		
150	300	0	Destroyed	0	0	Good	0	0	Good	0	0	Good	0	0	Good	0	0	Good
None:																		
Check	0	0	Good	0	0	Good	0	0	Good	0	0	Good	0	0	Good	40	6	Poor
Culture No. 4: Wheat at 14.60 percent moisture content containing weevil eggs and early larval stages																		
150,000 r.e.p.:																		
151	0	0	Good	0	0	Good	0	0	Good	0	0	Good	75	25	Poor	0	0	Good
100,000 r.e.p.:																		
18	0	0	Good	0	0	Good	0	0	Good	0	0	Good	200	10	Destroyed	0	0	Good
20,000 r.e.p.:																		
60	0	0	Good	0	0	Good	200	0	Destroyed	0	0	Good	0	0	Good	0	0	Good
10,000 r.e.p.:																		
67	0	0	Good	0	300	Destroyed	0	200	Destroyed	200	50	Destroyed	1	0	Good	150	10	Destroyed
137	0	0	Good	200	2	Destroyed	0	0	Good	75	0	Poor	1	4	Fair	0	1	Good
206	0	0	Good	1	1	Good	175	0	Destroyed	100	10	Destroyed	0	0	Good	0	0	Good
298	0	0	Good	250	0	Destroyed	0	3	Fair	0	1	Good	0	0	Good	0	0	Good
None:																		
Check	0	0	Good	100	0	Destroyed	49	0	Destroyed	185	5	Destroyed	190	0	Destroyed	86	7	Destroyed
Culture No. 5: Wheat at 14.70 percent moisture content containing weevils in larval and pupal stages																		
150,000 r.e.p.:																		
152	0	0	Good	150	6	Destroyed	0	0	Good	0	0	Good	2	0	Good	150	0	Destroyed
223	100	5	Destroyed	0	0	Good	0	0	Good	0	0	Good	50	2	Poor	100	25	Destroyed
100,000 r.e.p.:																		
159	0	0	Good	0	0	Good	200	10	Destroyed	0	0	Good	150	0	Destroyed	20	0	Poor
232	200	10	Destroyed	0	0	Good	0	0	Good	0	0	Good	125	25	Destroyed	125	25	Destroyed
20,000 r.e.p.:																		
131	0	0	Good	0	0	Good	50	150	Destroyed	0	0	Good	0	0	Good	0	0	Good
10,000 r.e.p.:																		
68	0	0	Good	0	400	Destroyed	0	250	Destroyed	250	0	Destroyed	0	0	Good	50	10	Destroyed
138	0	0	Good	100	10	Destroyed	250	0	Destroyed	200	0	Destroyed	0	4	Fair	4	1	Fair
207	0	0	Good	0	10	Poor	250	0	Destroyed	0	0	Good	0	1	Good	0	0	Good
299	0	0	Good	0	3	Destroyed	150	10	Destroyed	2	2	Good	0	0	Good	0	0	Good
None:																		
Check	67	8	Destroyed	153	0	Destroyed	250	10	Destroyed	200	10	Destroyed	130	0	Destroyed	85	9	Destroyed
Culture No. 6: Wheat at 15.60 percent moisture content containing weevils in larval, pupal, and adult stages																		
100,000 r.e.p.:																		
160	0	0	Good	1	0	Good	0	0	Good	0	0	Good	0	0	Good	0	0	Good
30,000 r.e.p.:																		
194	0	0	Good	0	0	Good	150	0	Destroyed	0	0	Good	0	0	Good	0	0	Good
10,000 r.e.p.:																		
69	0	50	Destroyed	0	200	Destroyed	0	0	Good	1	0	Good	0	1	Good	0	0	Good
139	200	20	Destroyed	150	12	Destroyed	0	4	Fair	0	0	Good	0	1	Good	100	0	Destroyed
208	1	12	Poor	120	10	Destroyed	0	4	Fair	0	1	Good	0	0	Good	1	1	Good
300	0	2	Fair	0	0	Good	0	0	Good	0	3	Good	0	0	Good	0	0	Good
None:																		
Check	210	15	Destroyed	200	10	Destroyed	250	5	Destroyed	175	10	Destroyed	80	0	Destroyed	95	9	Destroyed
Culture No. 7: Wheat at 16.40 percent moisture content containing weevils in pupal and adult stages																		
150,000 r.e.p.:																		
14	0	0	Good	0	0	Good	0	0	Good	0	0	Good	0	0	Good	1	0	Good
154	250	10	Destroyed	0	0	Good	0	0	Good	0	0	Good	0	0	Good	25	10	Poor
60,000 r.e.p.:																		
35	1	0	Fair	0	0	Good	0	0	Good	0	0	Good	0	0	Good	0	0	Good
174	0	1	Fair	0	0	Good	0	0	Good	0	0	Good	0	0	Good	0	0	Good
50,000 r.e.p.:																		
181	7	0	Fair	0	0	Good	0	0	Good	0	0	Good	0	0	Good	0	0	Good
20,000 r.e.p.:																		
292	150	6	Poor	0	0	Good	0	0	Good	0	0	Good	0	0	Good	0	0	Good
10,000 r.e.p.:																		
70	0	50	Destroyed	0	300	Destroyed	0	0	Good	0	0	Good	50	150	Destroyed	50	10	Destroyed
140	250	0	Destroyed	250	6	Destroyed	0	2	Good	2	5	Fair	0	0	Good	150	20	Poor
209	150	10	Destroyed	0	0	Good	1	1	Fair	0	0	Good	0	0	Good	3	2	Fair
301	300	0	Destroyed	0	0	Good	0	0	Good	0	0	Good	0	0	Good	0	0	Good
None:																		
Check	275	6	Destroyed	220	10	Destroyed	200	5	Destroyed	150	0	Destroyed	50	10	Destroyed	65	2	Destroyed

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Figure 5.--Results of irradiation of pupal stage of the rice weevil. Adult emerged from pupal case after treatment but was unable to get all the way out of the wheat kernel before death. (Slightly retouched photograph.)

Effects of Cathode Rays on the Wheat

The results of this phase of the work have been reported by Soderholm and Walker (8). They found that doses up to 200,000 r.e.p. did not stop the wheat seeds from germinating. However, none of the embryonic plants were able to continue development if the seed had received a dose of 40,000 r.e.p. or more. Doses from 10,000 to 30,000 r.e.p. prevented some plants from continuing development and reduced the vigor of the others.

FINDINGS

Although this report covers the results of only one test, several points were established by the test:

1. Cost of operation. Precise figures on the cost of treatment are not available, but on the basis of the data obtained in this test, the energy cost would appear to be about 0.013 cents per bushel of wheat, a very low figure. However, it is probable that the amortization and maintenance of the equipment will be the greater part of the cost.
2. Adult rice weevils required an exposure of 100,000 r.e.p. to cause instant death.
3. Weevils exposed to 20,000 to 30,000 r.e.p. lived for only a week and did not reproduce.
4. Weevils exposed to 10,000 r.e.p. lived for 7 to 8 weeks after irradiation but with a small amount of reproduction.
5. Weevils not exposed to radiation lived 6 to 8 months with normal reproduction rate.
6. The egg stage of the rice weevil was the stage most susceptible to the cathode rays. A dosage of 10,000 r.e.p. prevented the eggs from hatching.
7. Within the range of moisture content of the wheat used in this test (12.55 to 14.75 percent), there appeared to be no differences in the effects of the radiation.

LITERATURE CITED

(1) Baker, V. H., Taboada, O., and Wiant, D. E.
1953. Some Effects of Accelerated Electrons or Cathode Rays on Certain Insects and on the Wheat and Flour Which They Infest. Mich. Agr. Expt. Sta. Quart. Bul. 36(1): 94-106.

(2) Bushland, R. C., and Hopkins, D. E.
1951. Experiments With Screw-Worm Flies Sterilized by X-Rays. Jour. Econ. Ent. 44(5): 725-731.

(3) Charlton, E. E., Westendorp, W. F., Dempster, L. E., and Hotaling, G.
1939. A New Million-Volt X-ray Outfit. Jour. Appl. Phys. 10: 374-385.

(4) Coolidge, W. D., and Moore, C. N.
1932. Experimental Study of Cathode Rays Outside of the Generating Tube. Gen. Elect. Rev. 35(8): 413-417.

(5) Duggar, B. M.
1936. Biological Effects of Radiation. 2 vol. 1, 342 pp. New York.

(6) Dunn, C. G., Campbell, W. L., Fram, H., and Hutchins, A.
1948. Biological and Photo-Chemical Effects of High Energy, Electrostatically Produced Roentgen Rays and Cathode Rays. Jour. Appl. Phys. 19: 605-616.

(7) Hassett, C. C., and Jenkins, D. W.
1952. Use of Fission Products for Insect Control. Nucleonics 10(12): 42-46.

(8) Soderholm, L. H., and Walker, E. R.
1955. Effect of Cathode Rays on Germination and Early Growth of Wheat. Bot. Gaz. 116(3): 281-290.

(9) Trump, J. G., and Van de Graaff, R. J.
1948. Irradiation of Biological Materials by High Energy Roentgen Rays and Cathode Rays. Jour. Appl. Phys. 19: 599-604.

(10) Urbain, W. M.
1953. Facts about Cold Sterilization. Parts I and II. Food Engin. 25(2): 45, 46, 204-208; 25(3): 77, 78, 131, 133.

(11) Yeomans, A. H.
1952. Radiant Energy and Insects. U.S. Dept. Agr. Yearbook 1952. pp. 411-421.

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