THE EFFECT OF CATHODE RAY IRRADIATION ON SPROUTING, WEIGHT LOSS AND OXYGEN CONSUMPTION OF POTATOES

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THE EFFECT OF CATHODE RAY IRRADIATION ON SPROUTING, WEIGHT LOSS AND OXYGEN CONSUMPTION OF POTATOES

By

RICHARD WILLIAM TAYLOR

AN ABSTRACT

Submitted to the School for Advanced Graduate Studies of
Michigan State University of Agriculture and
Applied Science in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE

Department of Farm Crops

Year 1958

Approved Donald R. Isleib

RICHARD WILLIAM TAYLOR ABSTRACT

Russet Rural, Sebago, and Katahdin potatoes were irradiated with cathode rays at dosages of 0, 2,500, 5,000, and 10,000 rep both early and late in the storage season, and stored at 44 degrees F. and 92 percent relative humidity for four months to determine the effect of cathode ray irradiation on sprouting, weight loss and oxygen consumption.

Irradiation inhibited sprouting of all three varieties when applied either early or late in the storage season. As the dosage increased, sprouting was correspondingly less. At a dosage of 10,000 rep sprouting was negligible with all varieties regardless of time of irradiation.

The rate of weight loss and the weight loss exclusive of sprouting were dependent on the variety and the time of irradiation. In general it seemed that the highest level of irradiation caused a higher rate of loss than the control during the first month, subsequently becoming lowest during the fourth month. Irradiation affected the total weight lost due to respiration and transpiration, depending on the variety and the time of irradiation. With Russet Rural this weight loss was increased slightly with increasing irradiation in the early experiment, but remained essentially the same as the control in the late experiment. Sebago reacted similarly in both experiments, weight loss increasing slightly as the dosage increased to 10,000 rep. Katahdin was not affected by increased dosages of irradiation during the early experiment, but increased in weight loss during the late experiment.

Oxygen consumption was affected materially by all dosages during the first experiment. Oxygen consumption of Russet Rural was highest at 48 hours

(750 percent of control) followed by a gradual decline to essentially the same as the control at four months. Sebagos were greatest at 96 hours, followed by a similar decline to that of the control or slightly less. With Katahdin the rate of oxygen consumption fluctuated from 400 to 700 percent of the control between 24 hours and two months. After two months the rate declined gradually to slightly less than the control at four months.

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INTRODUCTION

Sprouting and excessive weight loss due to shrinkage in storage have long been problems in the potato industry. Generally, stored potatoes will lose from one to six percent of their weight per month, depending on storage conditions. Temperatures between 40 and 50 degrees F. delay sprouting for several months but unrefrigerated storage is usually not feasible beyond early spring because of the seasonal rise in temperature. Even with refrigeration it is difficult to hold untreated potatoes later than May.

Recent investigations into the use of ionizing radiation as a sprout inhibitor have been part of a large-scale attempt to utilize the waste fuels of nuclear reactors. Gamma irradiation in particular has been extensively investigated with one of the main problems arising from the fact that the rays pass completely through the tuber. Indications are that such complete penetration may cause mechanical damage to intercellular structure, possible internal blackening, and inhibition of the wound-healing process.

Gamma radiation consists of electromagnetic waves occurring in the range from 10^{0} to 10^{-3} angstrom units, while cathode rays consist of electrons which have been accelerated by electrostatic forces. Three terms are used to express the radiation dosage: roentgen (r), rad, and roentgen-equivalent-physical (rep). For the purposes of this experiment the three terms will be used synonymously.

The depth of penetration of electrons depends, among other things, upon the density of the material being irradiated and the kinetic energy

of the electrons expressed in million-electron volts (MEV). In this experiment a one MEV electron accelerator was used as the radiation source. The percent entrance of ionization of this machine, as shown by Nicholas (1958), decreases from 100 percent at zero depth after an initial rise to 120 percent at 0.5 millimeter depth. For potatoes the maximum depth at which ionization occurs is approximately four millimeters.

The purpose of this experiment was to observe the effects of four different dosages of cathode-ray irradiation on sprouting, weight loss, and oxygen consumption of three varieties of potatoes, in comparison to results obtained using similar dosages of gamma irradiation. The experiment was duplicated to include irradiation both early and late in the storage season. Experiment I was started in December, 1957, and continued through April, 1958. Experiment II began in March, 1958, and ended in July, 1958.

REVIEW OF LITERATURE

Little has been published concerning the use of cathode-ray irradiation to inhibit potato sprouting, although the use of gamma rays has been investigated rather extensively in the United States, in England, and in the U.S.S.R. The United States Army Quartermaster Corps has been particularly interested in irradiation as a means of preserving potatoes as well as other fresh food products for military use.

Sprouting and weight loss. Brownell, et al. (1957) reported that Idaho-grown Russet Burbank seed potatoes irradiated with gamma rays in the late spring sprouted less than those treated in the fall or early winter. A dosage of 15,000 rep appeared to be optimum regardless of storage temperature. Tubers receiving 5,000 rep developed sprouts three to five millimeters long at 45 degrees F. after five months. Weight loss was found to decrease logarithmically with increasing dosages up to 15,000 rep when the tubers were stored 140 days at 50 degrees F. and 90 percent humidity. This behavior has lent support to a hypothesis that weight loss is proportional to the number of living cells, if the cells are inactivated by a random, statistical process. However, a different explanation was necessary to interpret the effect of irradiation on Sebago and Russet Rural tubers which were treated shortly after harvest. The Sebago variety increased in weight loss as the radiation dosage increased. Russet Rural was intermediate in response to irradiation, weight loss being largely independent of dosage. From these observations it was clear that the physiological differences between varieties must be considered in any explanation of weight loss due to radiation treatment.

In England, Burton and Hannan (1957) reported that lower doses of gamma radiation than were found necessary in research done in the United States were as effective in suppressing sprout growth. Using five varieties, sprout inhibition was essentially complete with dosages ranging from 5,000 to 8,500 rep.

Heiligman (1957) noted that, after two months' storage, weight loss of gamma irradiated tubers due to respiration and transpiration, decay, and sprouting was less than the controls. This occurred when the dosage was the minimum (10,000 rep) required for sprout inhibition. As the dosage increased above 10,000 rep weight loss also increased.

Russian workers, Rakitin and Krylov (1957), found that gamma rays in doses of 10,000 rep and 40,000 rep completely stopped the sprouting of one variety of potatoes, and sharply decreased weight loss. The tubers had been irradiated in March and stored for seven months "in the usual vegetable storage place." During this period, the control tubers lost 72 percent of their original weight while irradiated tubers lost only 9.7 to 11.8 percent.

In preliminary tests with two MEV cathode rays Hannan (1956) noted that a dosage of less than 50,000 rep may be sufficient to prevent sprouting of potatoes. However, further testing revealed that even at low levels the irradiated tissue was damaged. The irradiated portion of cut tubers browned more rapidly than untreated tubers.

Sparrow and Christensen (1954) report that although sprouting of the Katahdin variety was inhibited above 5,000 rep gamma irradiation, the treated tubers showed a greater rate of loss of weight than did the controls. After eight months storage the controls had lost a total of 9.7 percent

of their original weight (including sprouts) and those receiving 20,000 rep had lost 7.3 percent.

As stated previously, temperatures between 40 degrees and 50 degrees F. will delay sprouting while higher temperatures result in excessive sprouting and rotting. Sawyer and Dallyn (1955) reported that gamma irradiation of the Green Mountain variety above 10,000 rep gave complete sprout inhibition at temperatures of 40 degrees, 50 degrees and even 70 degrees F. after six months storage. Comparing these results with those obtained by Schwimmer et al. (1957), it was found that even under similar storage conditions there is a difference between varieties in response to irradiation. Russet Burbank tubers treated with 5,200 rep gamma radiation and stored at 40 degrees F. for 35 weeks sprouted very little; at a storage temperature of 70 degrees F., sprouts were 230 millimeters long.

Respiration. Nothing has yet been reported on the effect of cathode ray irradiation on potato respiration. Relatively few of the recent investigations concerning the effects of ionizing radiations on potatoes have dealt with measurements of respiration.

One of the first respiration investigations was performed by Sussman (1953) using small Irish Cobbler tubers. It was found that the respiratory gas exchange was markedly enhanced by doses of gamma and X-irradiation. The Q_{O_2} (mm.^{3} oxygen/hour/mg. fresh weight) increased from two to six-fold several hours after irradiation, then decreased. A similar increase in Q_{CO_2} (mm.^{3} carbon dioxide/hour/mg. fresh weight) was noted except that this increase occurred on the first day after irradiation, then decreased. In both cases the peaks were highest at 10,000 rep. In an attempt to explain this apparent radiation-induced increase in respiration, cytochrome

oxidase and tyrosinase activity were measured. The results indicated that only extremely high dosages had any effect on these systems, reducing tyrosinase activity by about one-half at 3,200,000 rep. Cytochrome oxidase activity was not appreciably affected.

Brownell et al. (1957) also studied respiration of irradiated tubers using both whole tubers and bud tissue slices. With the tissue slices, gamma irradiation up to 15,000 rep had no significant effect on respiration. Doses from 50,000 rep to 200,000 rep resulted in continued higher respiration as compared to the controls. Whole tubers gave results similar to the tissue slices at the higher doses. Compared to the controls the lower doses respired about 30 percent less than the controls the first day, followed by an increase to 60 percent greater the second day. By the thirteenth week, respiration had declined to a point about five percent less than the controls.

Studies by Rakitin and Krylov (1957) showed that during the six-weeks period following gamma irradiation at 10,000 rep the average rate of carbon dioxide evolution decreased from about 450 percent of control the first week to a value approximately the same as the control at the end of six weeks.

Gustafson et al. (1957) conducted a comprehensive study of the effects of gamma irradiation on the respiration of whole tubers and tissue slices. It was demonstrated that the carbon dioxide production of whole tubers receiving dosages of 5,000, 15,000, and 25,000 rep increased shortly after irradiation and remained at a high level for several weeks. This was followed by a decline to a level similar to that of the controls. Treatments of 50,000 rep and higher caused respiration to remain high throughout the experiment. The oxygen consumption at the lower dosages

exhibited two peaks, the first day after irradiation, and during the third week. It was thought that the low oxygen consumption coupled with high carbon dioxide production was due to a "temporary aerobic fermentation". Since the respiration rate returned to a normal level after a period of time, it could be assumed that no permanent physiological changes were induced.

In summary, the following data have been gathered concerning the effects of ionizing radiation on potatoes:

1) Varieties differ in their response to irradiation treatment.

2) At the sprout-inhibiting levels and lower, irradiated tubers lose less weight than untreated tubers.

3) Irradiation doses higher than necessary for sprout inhibition may induce permanent physiological damage.

4) Storage temperature and irradiation dosage seem to be correlated with amount of sprouting.

5) Respiration rate of whole tubers and of potato tissue slices increases shortly after irradiation, followed by a gradual decline to that of untreated tubers.

6) The mechanism of radiation-induced effects on sprouting, weight loss, and respiration is still largely speculative.

EXPERIMENTAL

Three varieties of potatoes were used in this experiment: Russet Rural, Sebago, and Katahdin. A thousand pounds of each variety were obtained on November 12, 1957, from growers in Monroe,County, Michigan. The tubers were washed and transferred to wooden boxes, each box containing approximately 20 pounds. These were stored at 44 degrees F. and 92 percent relative humidity for five weeks prior to irradiation.

At the end of the five-week period 72 of the 144 boxes of potatoes were removed from storage, weighed, and irradiated the following day with four dosages of cathode rays: 0, 2,500, 5,000, and 10,000 rep. Each treatment was replicated six times.

The source of the cathode ray irradiation was the one MEV electron accelerator located in the Department of Agricultural Engineering at Michigan State University. A special conveyor, shown in Figure 1, was used which rotated the tubers as they passed beneath the electron tube. Conveyor speed was 33 1/3 feet per minute and the distance from the electron tube window to the conveyor rolls was 47 centimeters. Different levels of radiation were produced by varying the micro-amperage of the machine. After irradiation the tubers were returned to the storage.

Weight loss was determined by weighing the boxed tubers at monthly intervals. At the end of the four-month period all tubers were weighed, de-sprouted, and the sprouts weighed. Weight loss due to sprouts and due to shrinkage was then calculated. Observations were also made on the extent of sprouting.

Respiration measurements were made immediately preceding irradiation, and at intervals of 24, 48, and 96 hours, and 1, 2, 3, and 4 months after

Figure 1: Potato conveyor used for cathode ray irradiation. Cathode ray tube is visible at top of picture.

irradiation. Six tubers were used for each determination. All measurements on whole tubers were made within the storage compartment to avoid errors due to temperature variation. Prior to the measurement the tubers were placed in jars and left to respire for three hours. The cover of each jar was fitted with two 1/8-inch copper tubes. A rubber balloon was attached to the bottom of one tube to act as an expansion chamber when a sample of air was withdrawn. The second tube was left open to the atmosphere except when a sample was being withdrawn. All measurements were made with a Haldane-type Burrell gas analysis apparatus, model 39-507. Weight and volume measurements of the tubers within the jar were made at monthly intervals. Between determinations all tubers were stored in mesh bags within the storage compartment.

In an effort to obtain more accurate observations on the effect of irradiation on oxygen consumption, a preliminary study was done on the oxygen uptake of potato tissue slices. Three tubers of the Sebago variety, approximately two inches in diamter, were used from each treatment. The tubers had been irradiated 24 hours previous to use, and were stored at room temperature. From each tuber five cork-borer sections six millimeters in diameter were taken, and from each section one slice approximately one millimeter in thickness was removed. Neither the external 0.5 millimeter nor any bud tissue were used. At the same time a similar number of slices were obtained from the center of the tubers in order to ascertain whether or not there was any indirect effect of irradiation on the internal tissue. All slices were washed in ice water for a short period, then transferred to Warburg flasks containing three milliliters of phosphate buffer, pH 5.9, and 0.25 milliliters of 20 percent potassium hydroxide in the center well.

The temperature of the water bath was 26 degrees C. After a 15 minute period of equilibration, the manometer taps were closed and readings were taken at 15 minute intervals for two and one-half hours. The tissue slices were then removed and dried for dry weight determination.

EXPERIMENTAL RESULTS

Experiment I. There was a definite indication of a difference between varieties in response to cathode ray irradiation. As was expected, 10,000 rep resulted in the least amount of sprouting in all varieties. It appeared that the sprouts had started to grow but were inhibited after reaching about 1/8 inch in length. The amount of weight lost varied between varieties and between treatments. It may be seen in Figure 2 the extent to which sprouting occurred in Russet Rural at the end of four months. Figure 3 illustrates the percent of original weight lost from Russet Rural due to sprouting, and due to respiration and transpiration at the end of four months. Total weight loss was least, about six percent, with a treatment of 5,000 rep. At 10,000 rep the total weight loss increased slightly to seven percent of the original weight. This may indicate some mechanical damage to the cells, facilitating moisture loss.

The appearance of the Sebago variety at the end of four months is shown in Figure 4. Total weight loss may be seen in Figure 5. Weight loss through respiration and transpiration increased nearly one percent with each dosage increment of 2,500 and 5,000 rep. At 10,000 rep, sprouting was reduced still further while other losses remained essentially the same. Here, also, it seems that irradiation may have damaged the cells, although the lack of change at 10,000 rep is unexplained. It is possible, however, the irradiation at this level caused a decrease in the permeability of the cell walls.

Katahdin was the most sensitive to irradiation in regard to sprouting. This is apparent in Figure 6. Sprouts on the irradiated tubers were

Control

2,500 rep

5,000 rep

10,000 rep

Figure 2: Effect of increasing dosages of cathode ray irradiation on sprouting of Russet Rural after four months of storage at 44 degrees F. and 92 percent relative humidity. Irradiated December, 1957.

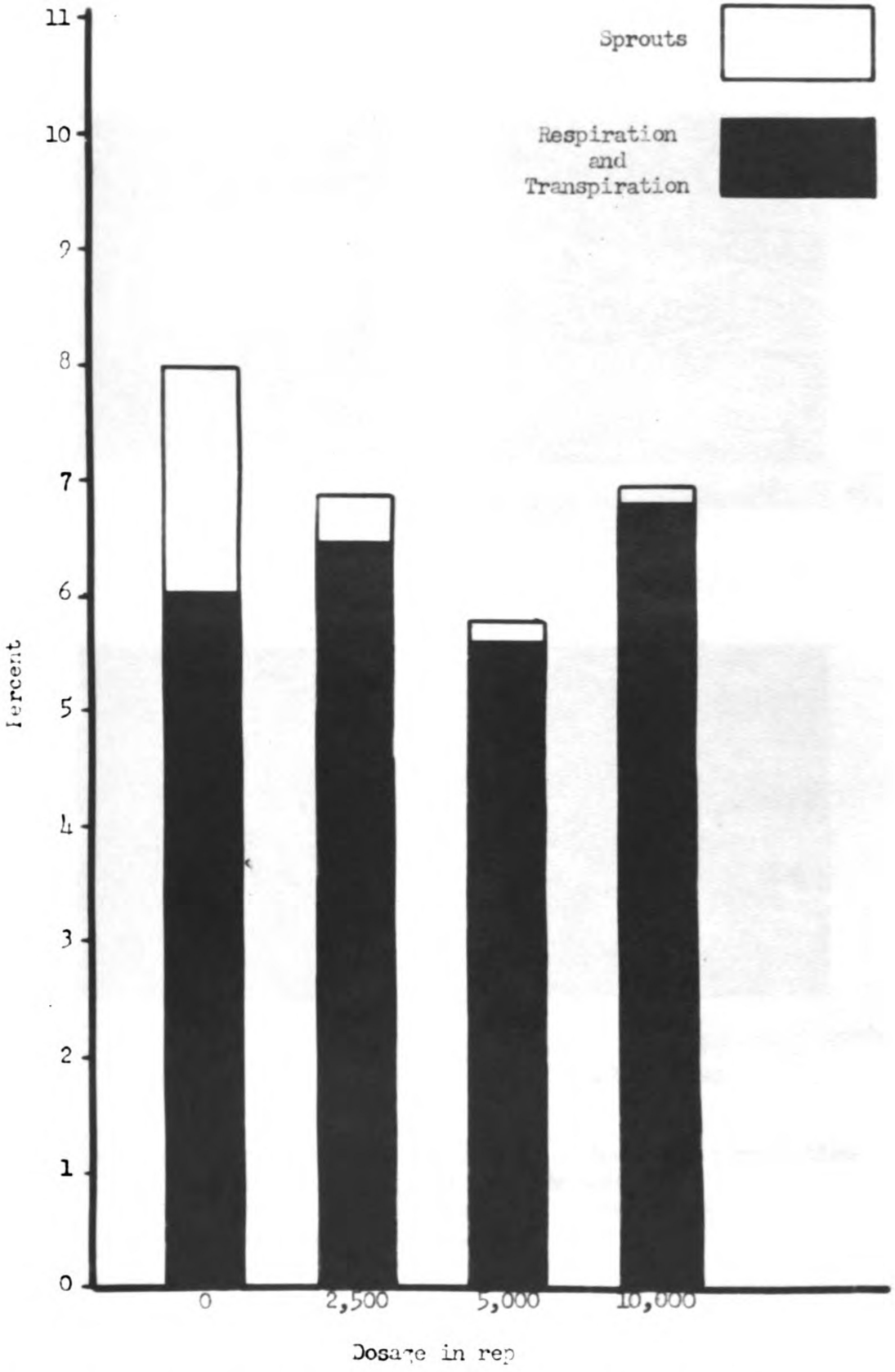
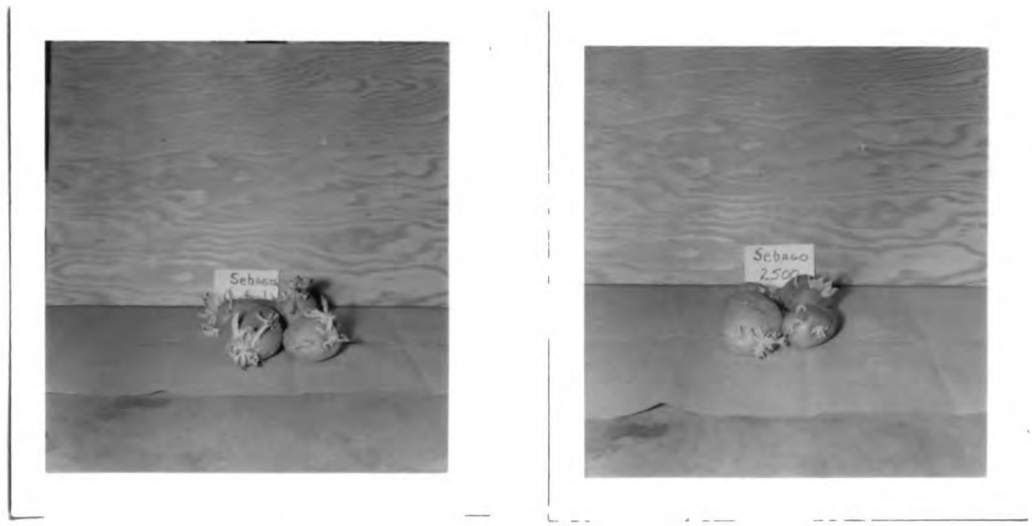
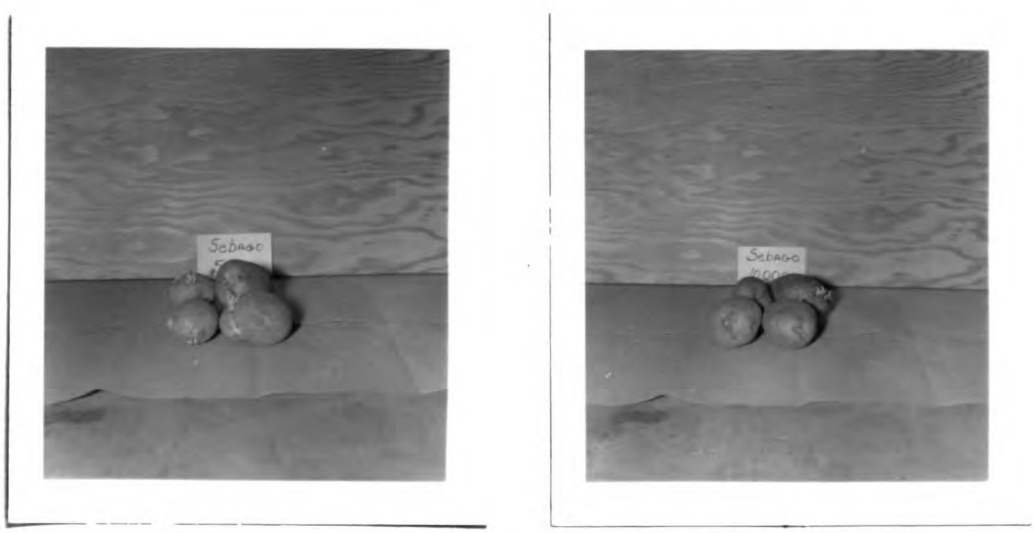


Figure 3: Total weight lost of irradiated Russet Rural tubers, expressed as percent of original weight.



Control

2,500 rep



5,000 rep

10,000 rep

Figure 4: Effect of increasing dosages of cathode ray irradiation on sprouting of Sebago after four months of storage at 44 degrees F. and 92 percent relative humidity. Irradiated December, 1957.

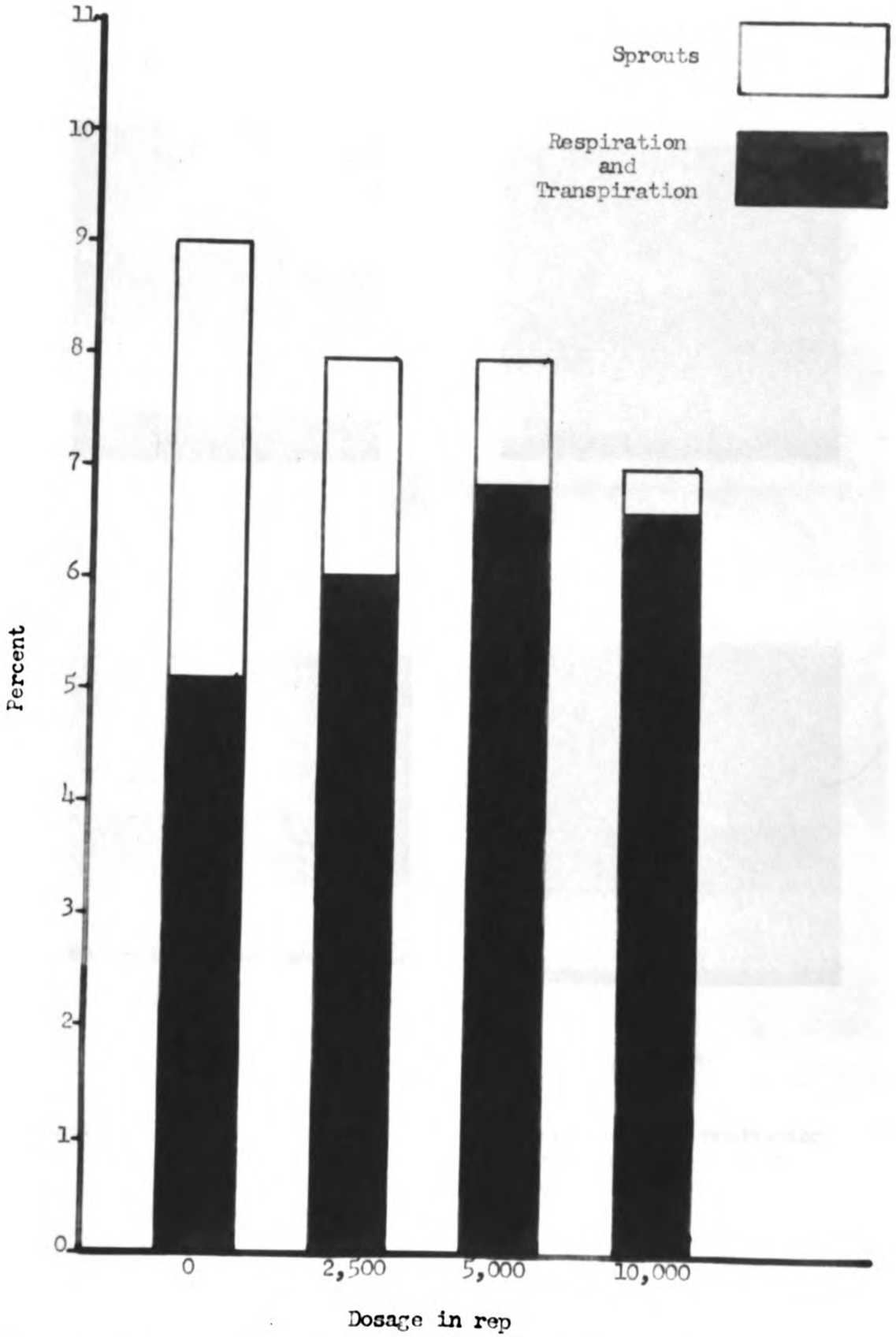
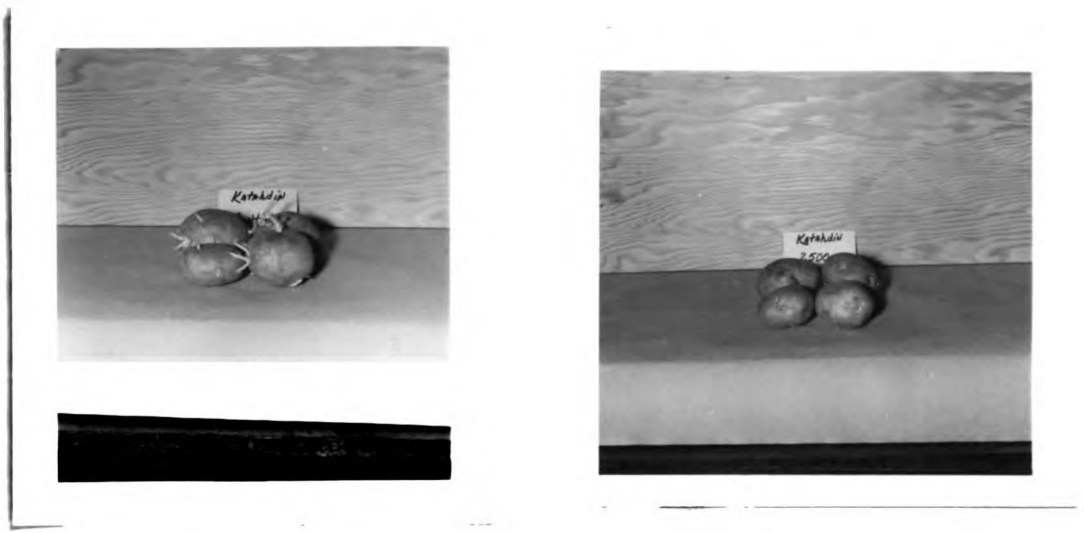
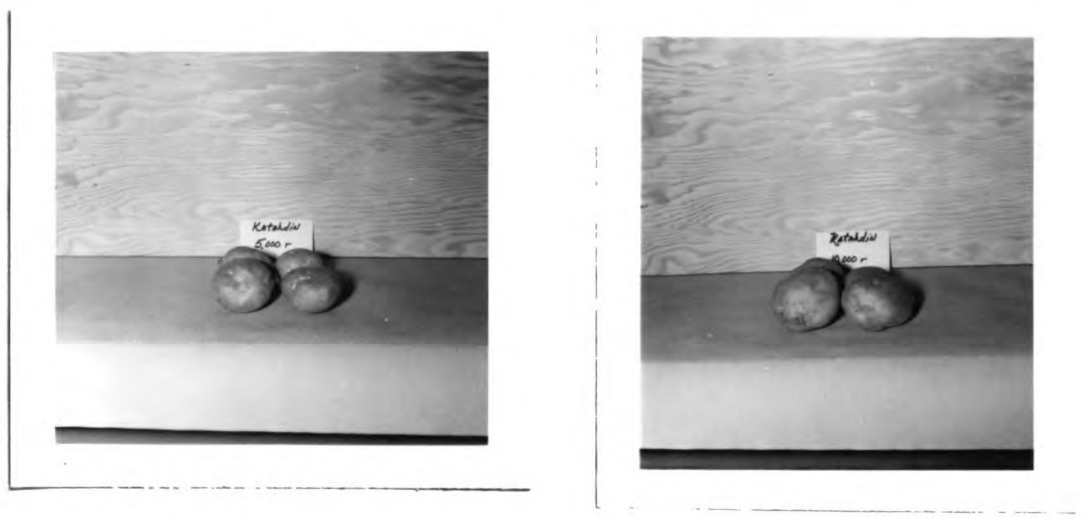


Figure 5: Total weight lost of irradiated Sebago tubers, expressed as percent of original weight.



Control

2,500 rep



5,000 rep

10,000 rep

Figure 6: Effect of increasing dosages of cathode ray irradiation on sprouting of Katahdin after four months storage at 44 degrees F. and 92 percent relative humidity. Irradiated December, 1957.

1/8 inch or less in length. Figure 7 shows that irradiation had very little if any effect on respiration and transpiration losses.

Figures 8, 9, and 10 illustrate the effect of irradiation on the monthly weight loss of the three varieties. Russet Rural showed its sensitivity to increasing dosages at one month when weight loss was greatest, 2.6 percent at 10,000 rep. Thereafter, however, the rate of loss declined with time in the irradiated tubers. During the fourth month the rate of loss for untreated tubers rose to 2.6 percent. At 10,000 rep during this same period the rate was 1.6 percent. With the Sebago variety the rate of weight loss was fairly steady regardless of treatment up to the third month. Between the third and fourth months a dosage of 10,000 rep substantially reduced the loss rate, which was 2.4 percent while the control was 3.7 percent. The rate of weight loss of the Katahdin variety was essentially unaffected by irradiation, as shown by Figure 10.

The data on oxygen consumption of whole tubers showed a pattern similar to the results of Gustafson et al. (1957). Carbon dioxide production was also measured, but due to the amount of rubber tubing used and the high rate of diffusion of carbon dioxide through rubber, the reliability of the CO_2 data was in question and they have been omitted. With Russet Rural all irradiation treatments resulted in a sharp increase in oxygen consumption, up to 750 percent of the controls 48 hours after irradiation. This is illustrated in Figure 11. By 96 hours the rate had declined to approximately 400 percent of the controls. After a slight increase at one month the rate gradually declined until at the third and fourth month it was the same or slightly below that of the controls.

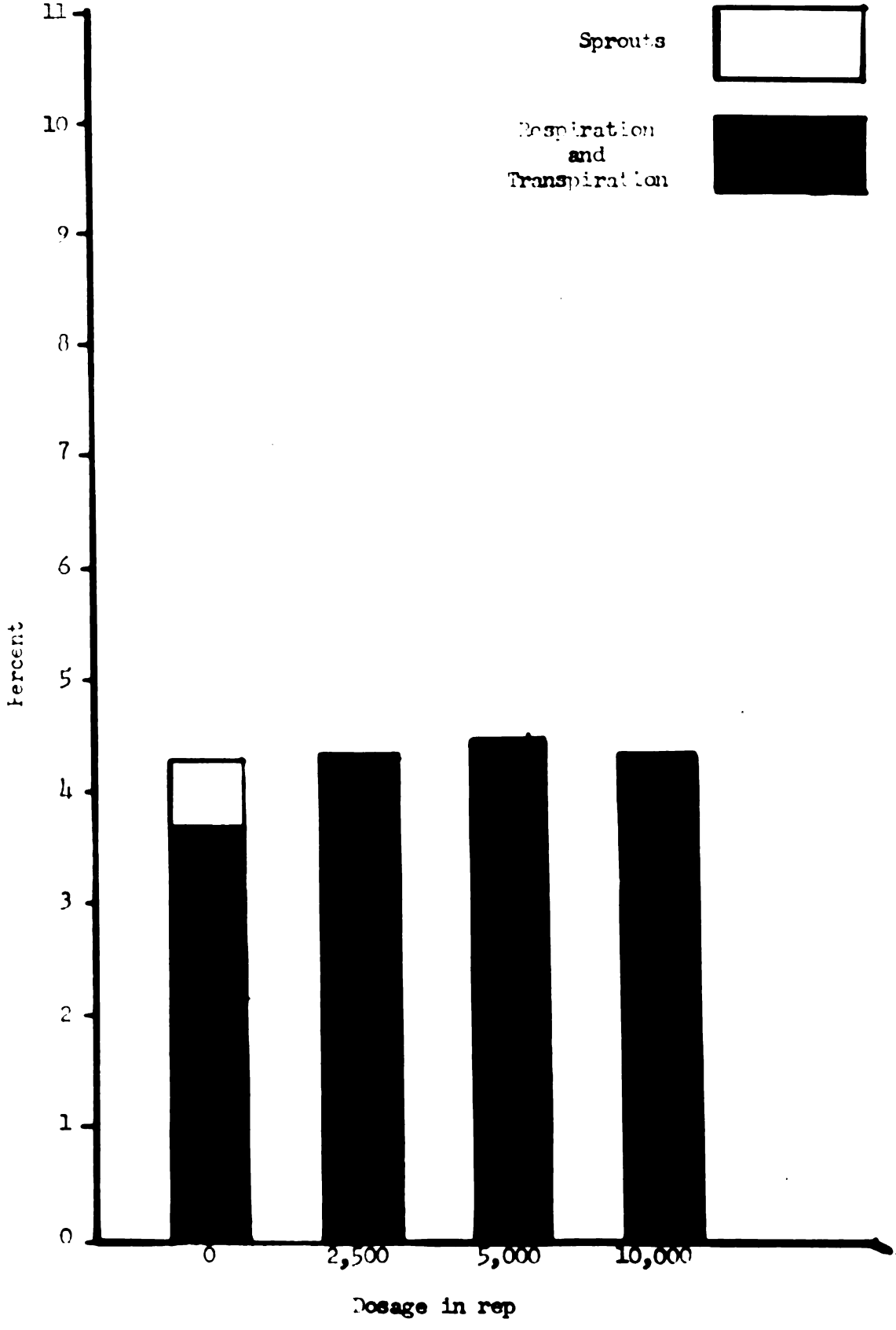


Figure 7: Total weight lost of irradiated Katahdin tubers, expressed as percent of original weight.

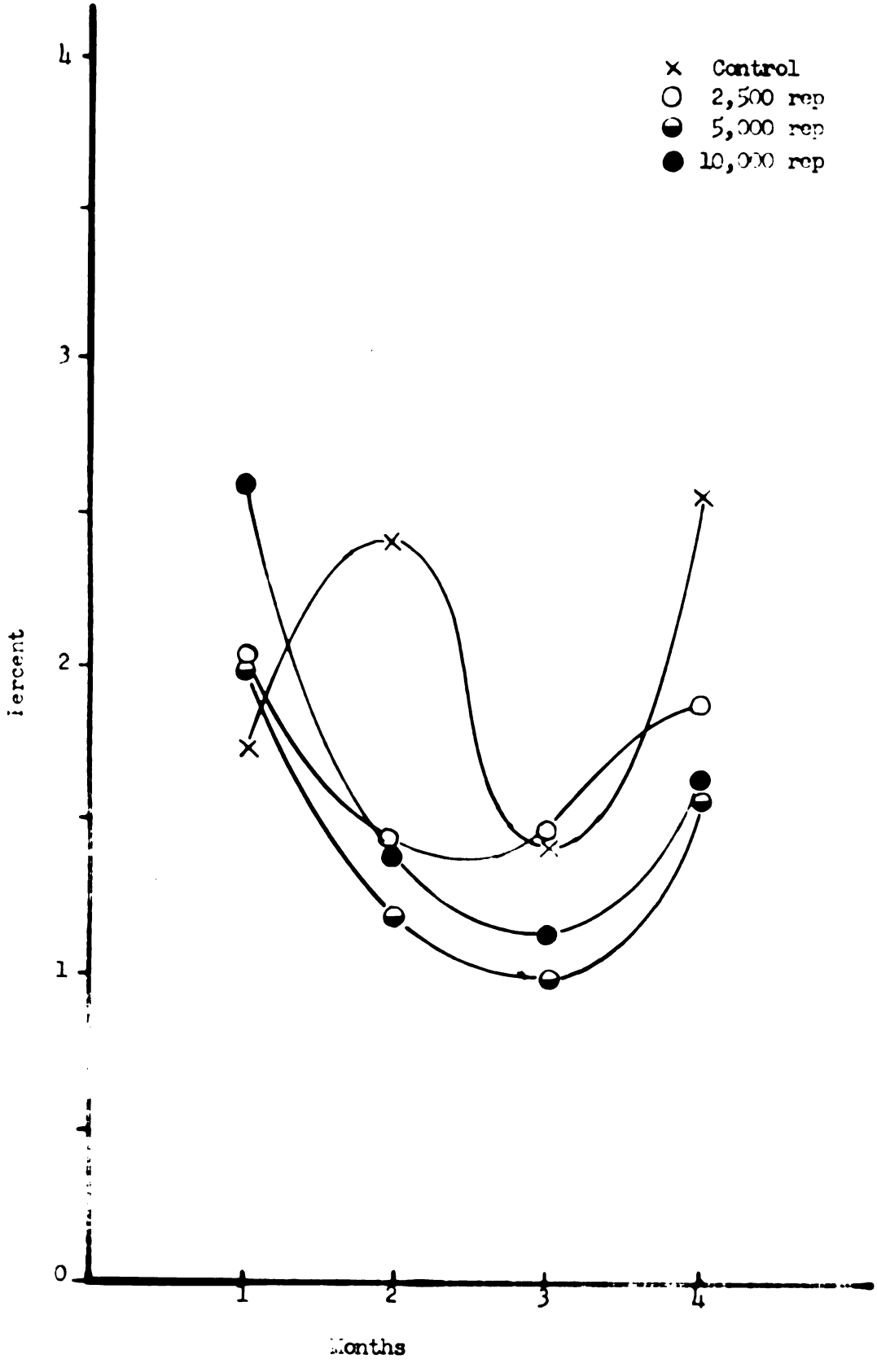


Figure 8: Rate of weight loss per month as affected by cathode ray irradiation. Expressed in percentage. Russet Rural var.

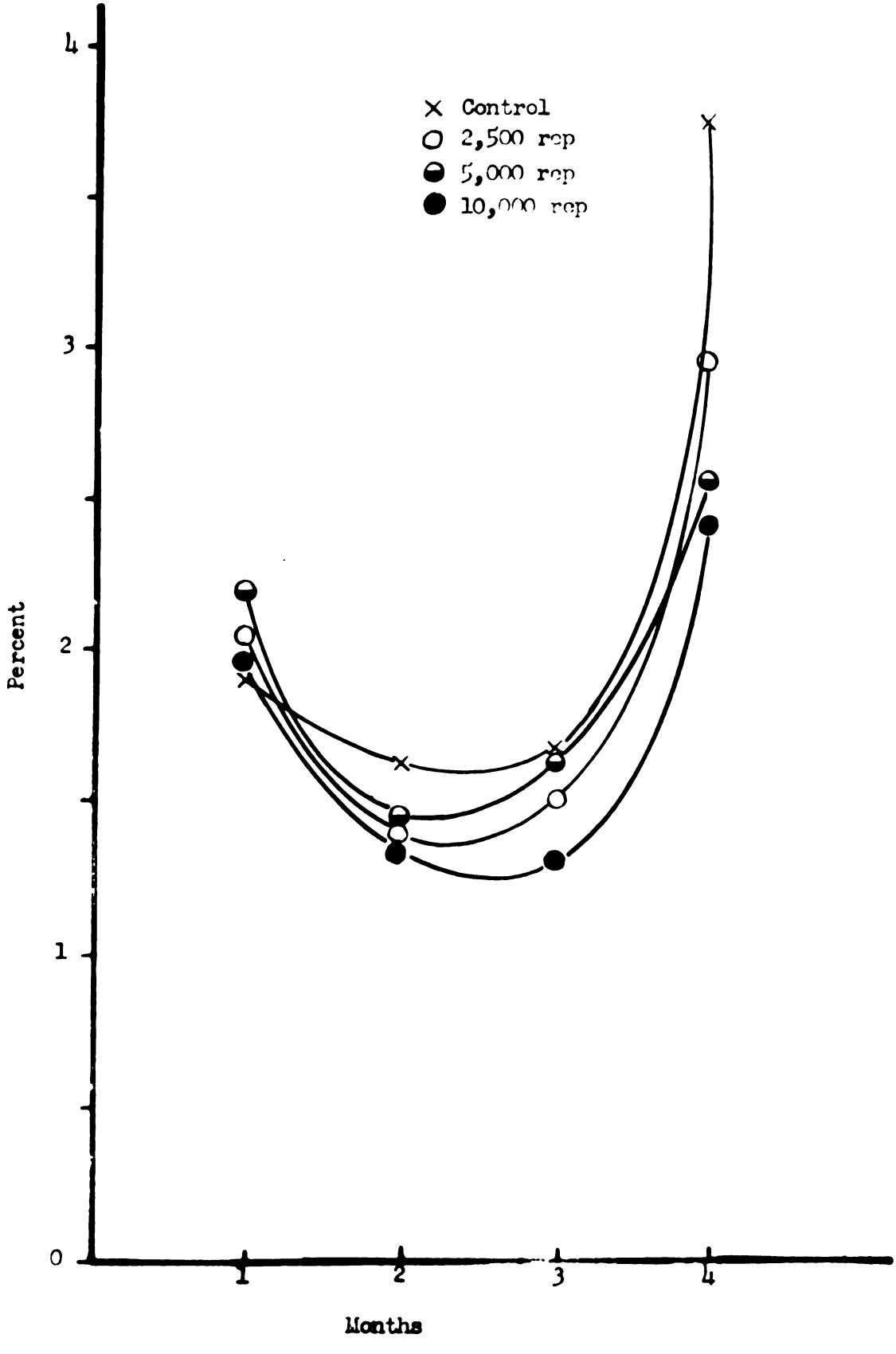


Figure 9: Rate of weight loss per month as affected by cathode ray irradiation. Expressed as percentage. Sebago var.

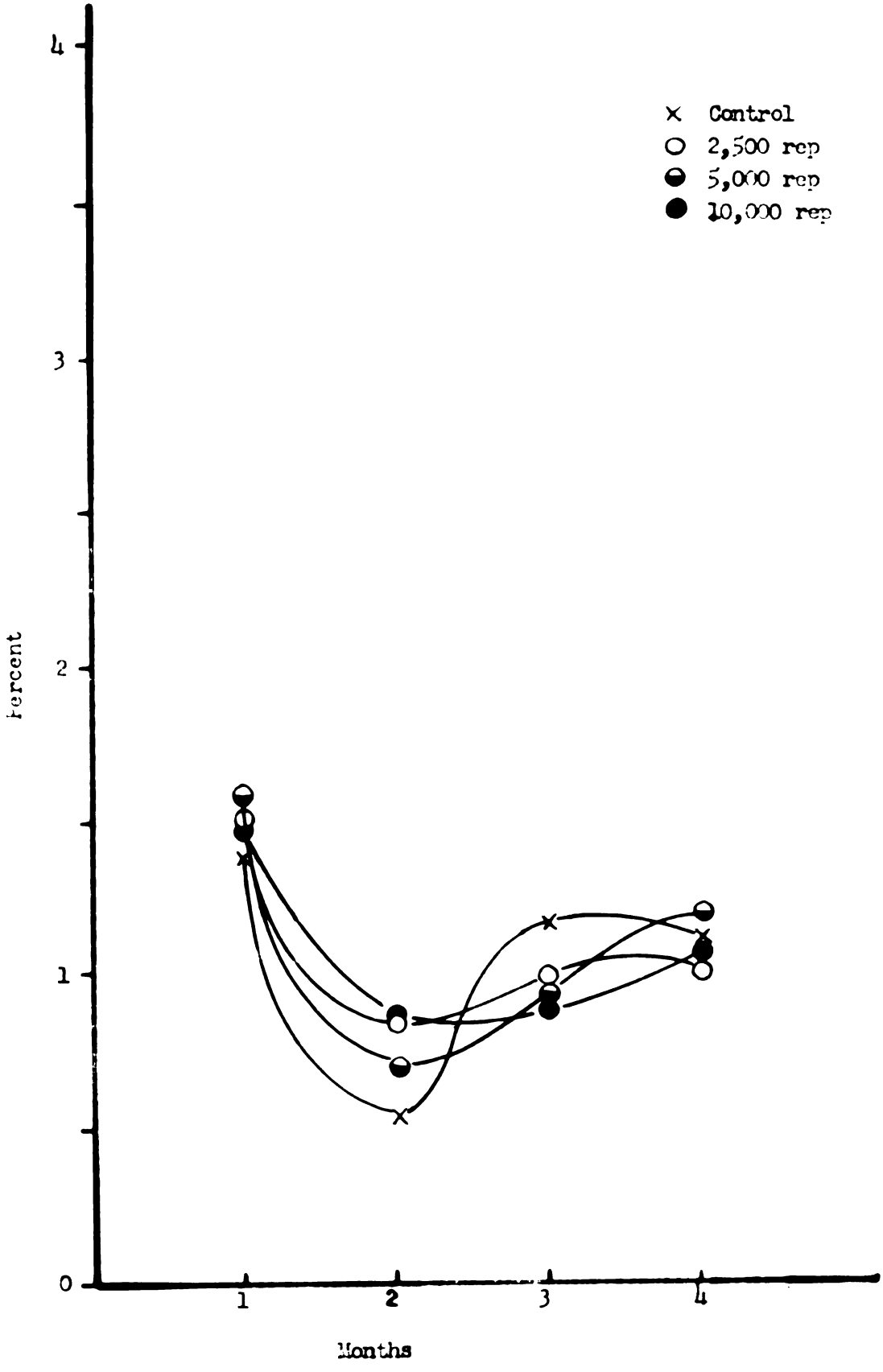


Figure 10: Rate of weight loss as affected by cathode ray irradiation. Expressed as percent per month. Katahdin var.

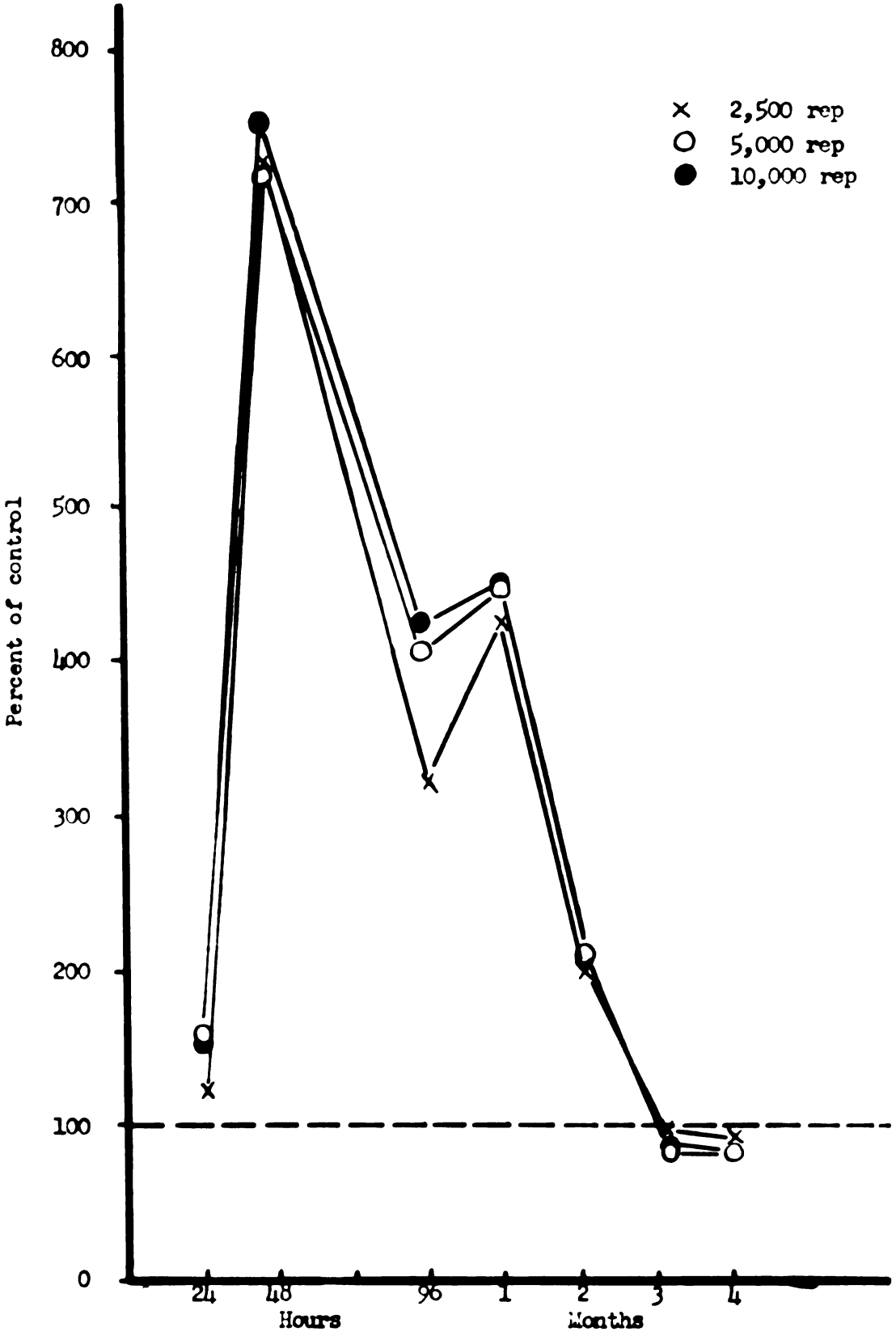


Figure 11: Effect of cathode ray irradiation on rate of oxygen consumption of whole Russet Rural tubers. Expressed as percent of control.

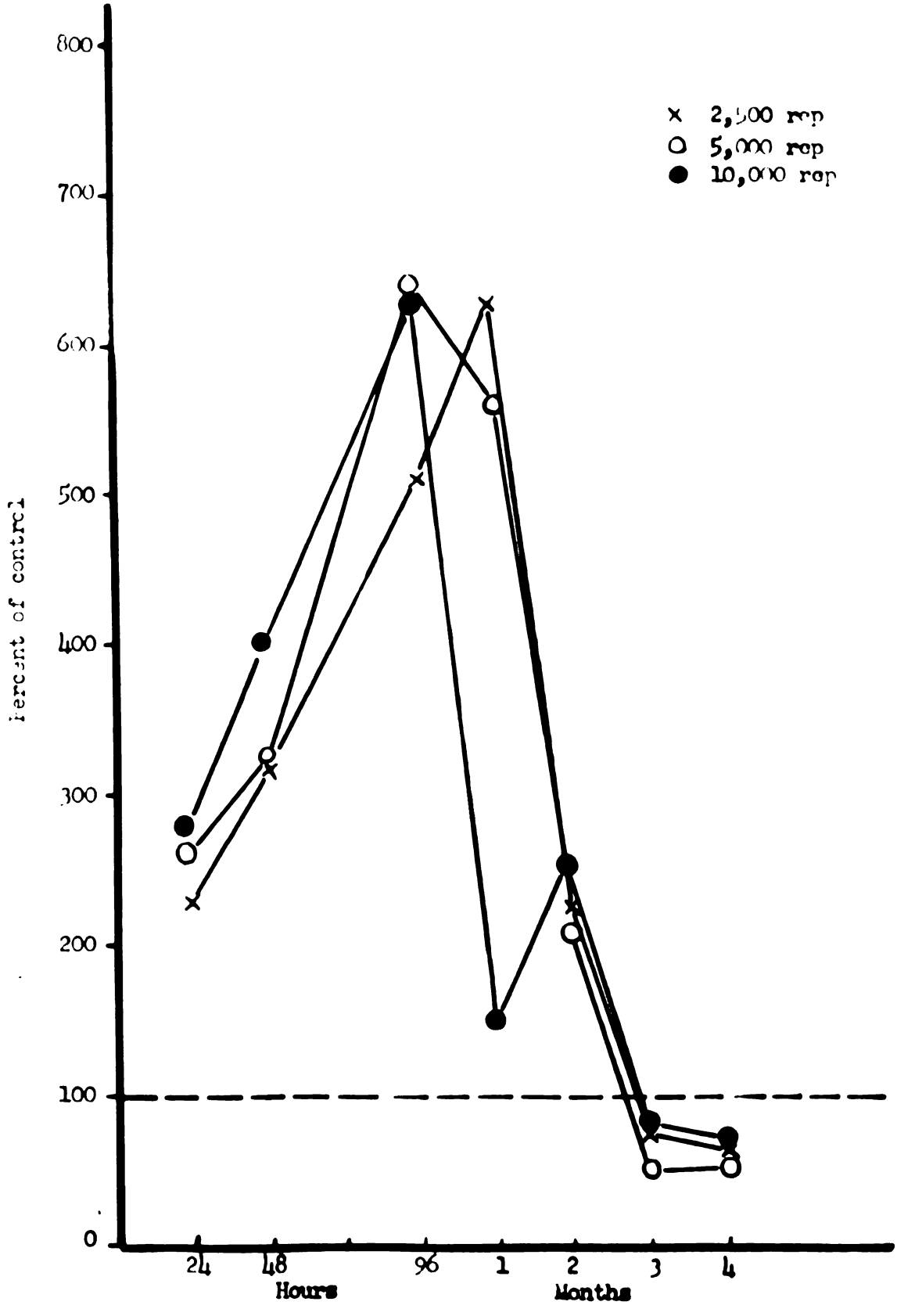


Figure 12: Effect of cathode ray irradiation on rate of oxygen consumption of whole Sebago tubers. Expressed as percent of control.

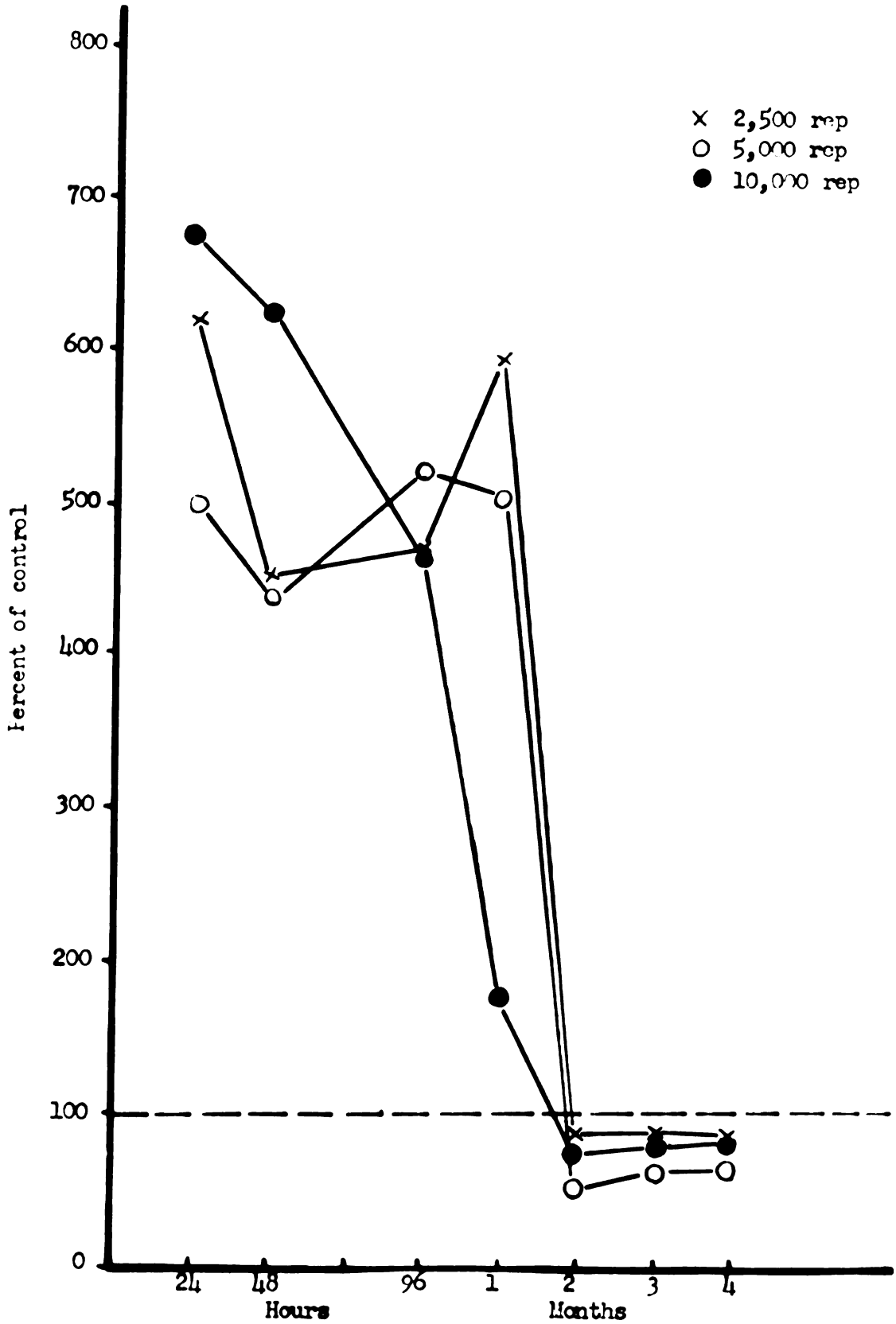


Figure 13: Effect of cathode ray irradiation on rate of oxygen consumption of whole Katahdin tubers. Expressed as percent of control.

The rate of oxygen consumption by Sebagos (Figure 12) was greatest at 96 hours with a dosage of 5,000 and 10,000 rep. The tubers treated with 2,500 rep did not reach their peak until one month after irradiation. The rates then steadily declined until at the third and fourth months when oxygen consumption was between 25 and 50 percent less than that of the controls.

The oxygen consumption of Katahdin (Figure 13) was somewhat erratic. A treatment of 2,500 rep resulted in two peaks, one at 24 hours, and one at one month. Two peaks again resulted from a treatment with 5,000 rep, one at 24 hours and one at 96 hours. The 10,000 rep treatment resulted in one pak of 675 percent of control at 24 hours, followed by a gradual decline until two months. Between two months and four months the rates of all the treated tubers had leveled off to 50 to 80 percent of the control.

Experiment II. The results obtained in this experiment were somewhat different from those in Experiment I. Figure 14 illustrates the effect of the different radiation treatments on sprouting of Russet Rural after four months. It will be noted that 10,000 rep was not as effective in inhibiting sprouting as was the case in the previous experiment. After four months sprouts made up 4.5 percent of the original weight of the control tubers while with a dosage of 10,000 rep sprouts represented only 0.6 percent of the original weight. The majority of the long sprouts appeared at the apical end of the tubers. In Figure 15 it will be noted that weight loss due to respiration and transpiration is essentially unaffected.

Sebago sprouted to nearly the same extent as Russet Rural. Again the majority of the sprouts on irradiated tubers appeared at the apical end. At the end of four months sprouting represented a loss of 8.4 percent in the controls, and only 0.2 percent of those irradiated at 10,000 rep.

Control

2,500 rep

5,000 rep

10,000 rep

Figure 14: Effect of increasing dosages of cathode ray irradiation on sprouting of Russet Rural after four months storage at 44 degrees F. and 92 percent relative humidity. Irradiated March, 1958.

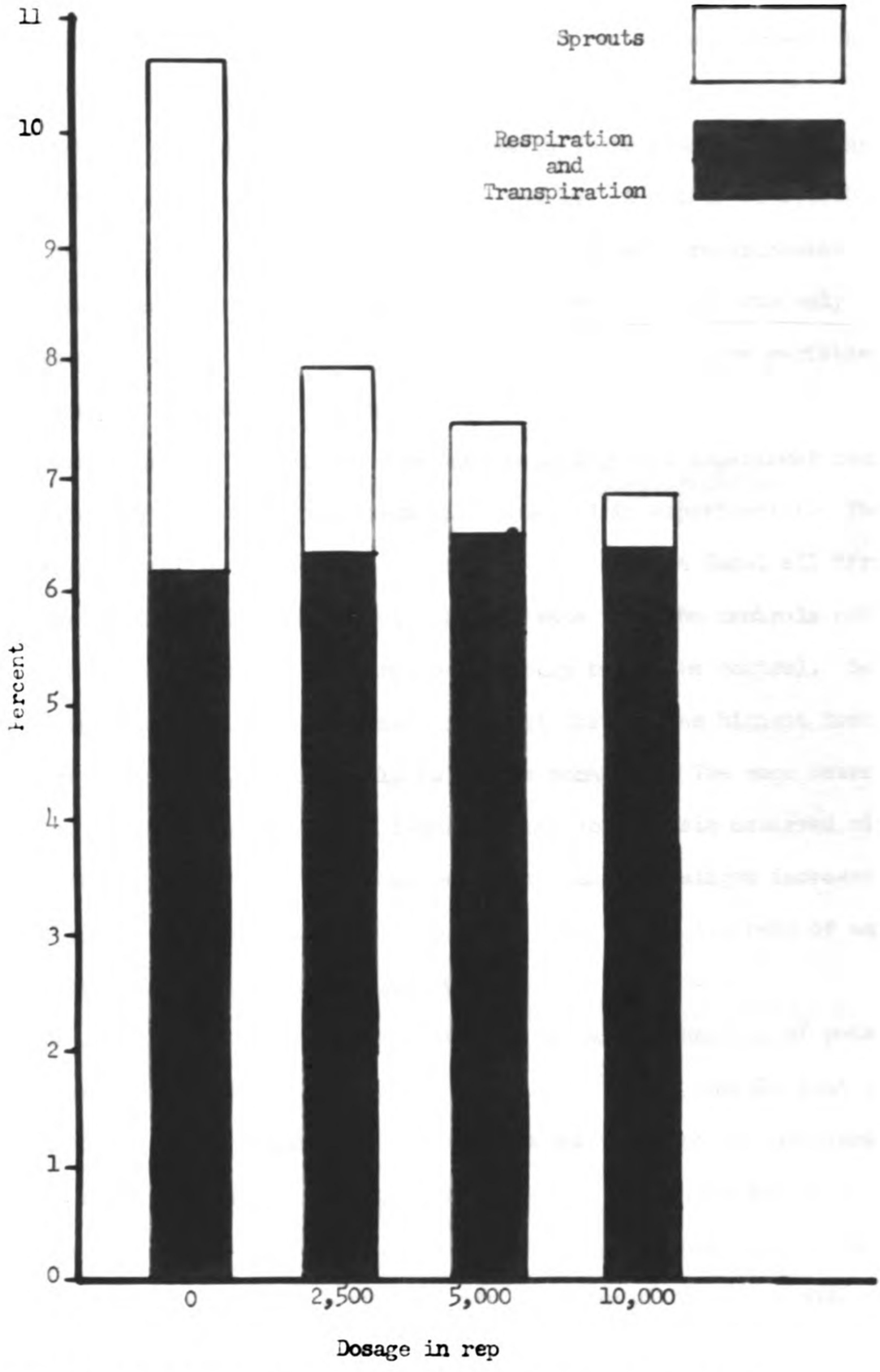


Figure 15: Total weight lost of irradiated Russet Rural tubers, expressed as percent of original weight.

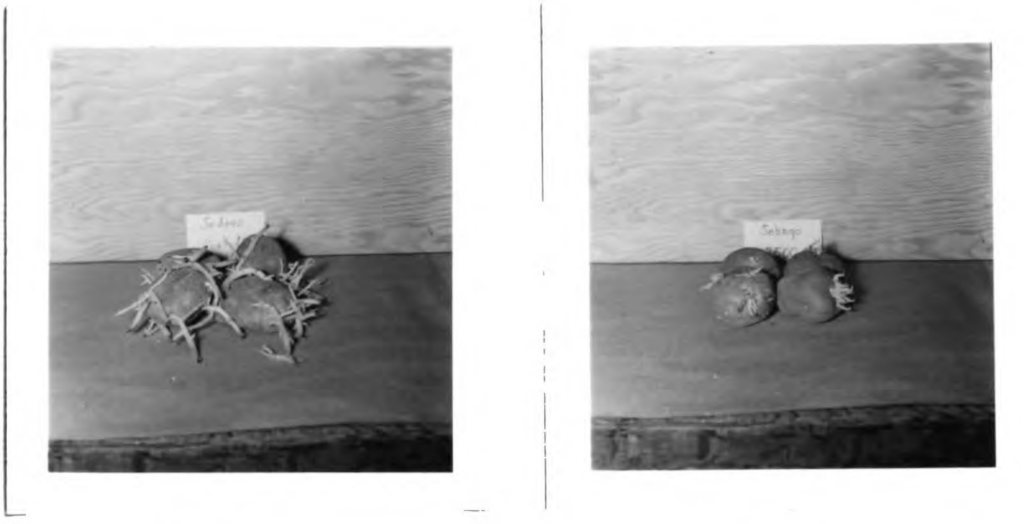
Irradiation seemed to be the cause of a rise of two percent in weight loss due to respiration and transpiration. See Figures 16 and 17.

Katahdins reacted essentially the same to increasing irradiation doses. This is illustrated in Figures 18 and 19. A dosage of 10,000 rep tended to increase the loss due to respiration and transpiration over a four month period, but the actual decrease in weight was only 0.2 percent. The rates at which weight was lost in the three varieties may be seen in Figures 20, 21 and 22.

Measurements of the oxygen consumption during this experiment resulted in considerably different data from that obtained in experiment I. The results are given in Figures 23, 24 and 25. With Russet Rural all irradiation treatments consumed oxygen at a higher rate than the controls until the third month, when the rate dropped slightly below the control. Sebagos reacted in essentially the same manner except that at the highest dosage the tubers stayed with or slightly below the controls. The same decrease was noted at three months. With Katahdins the lowest rate occurred with the two lowest dosages. The 10,000 rep level caused a slight increase during the first 96 hours. At two, three, and four months the rate of oxygen consumption was the same as the controls.

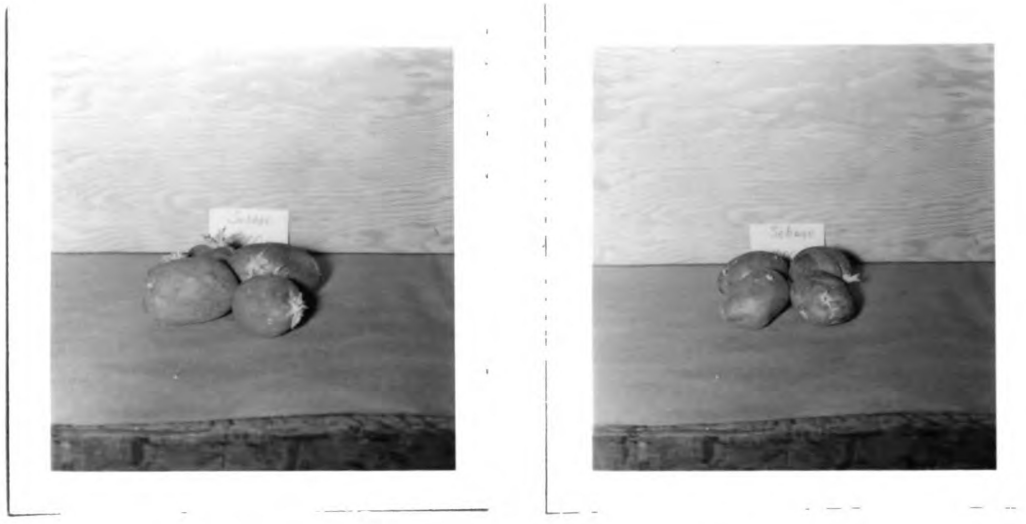
The results of the preliminary work on oxygen consumption of potato slices are shown in Figures 26 and 27. Although it is possible that the initial high rate in Figure 26, was due to a short period of equilibration, there is nevertheless an indication that irradiation at successively higher dosages caused a corresponding increase in oxygen consumption of tissue in the epidermal layer. The tissue from the interior of the tuber did not seem to be materially affected by cathode ray irradiation up to 10,000 rep.

The absolute figures for the oxygen consumption of whole tubers, treated and untreated, are given in Table 1. The effect of irradiation on respiration may be seen in the figures for Experiment I. The oxygen consumption was consistently higher with irradiated tubers up to the second month. After this time the rate was nearly the same as that of the controls. The data for Experiment II showed that there was essentially no difference in oxygen consumption between the controls and the irradiated tubers.



Control

2,500 rep



5,000 rep

10,000 rep

Figure 16: Effect of increasing dosages of cathode ray irradiation on sprouting of Sebago after four months storage at 44 degrees F. and 92 percent relative humidity. Irradiated March, 1958.

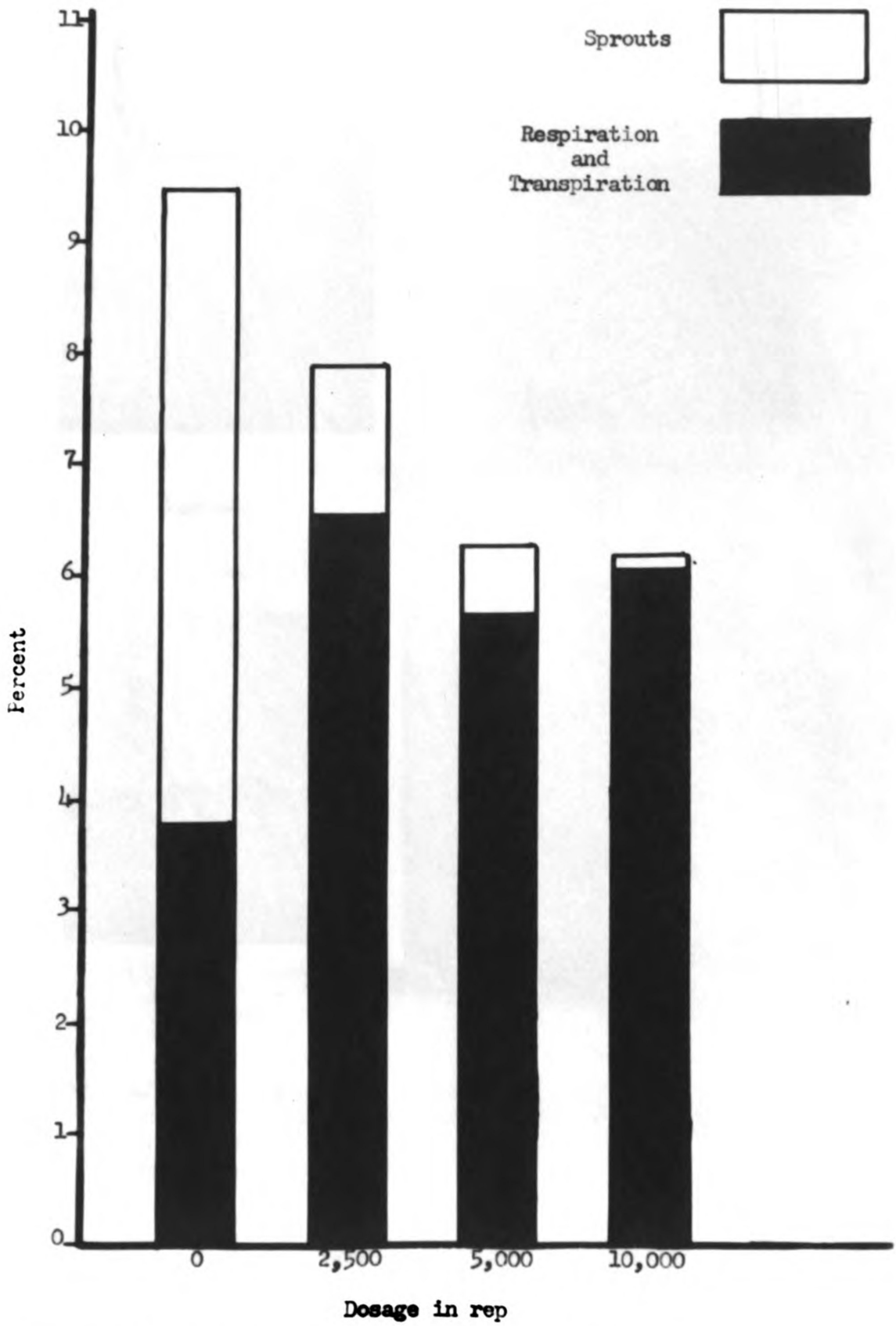
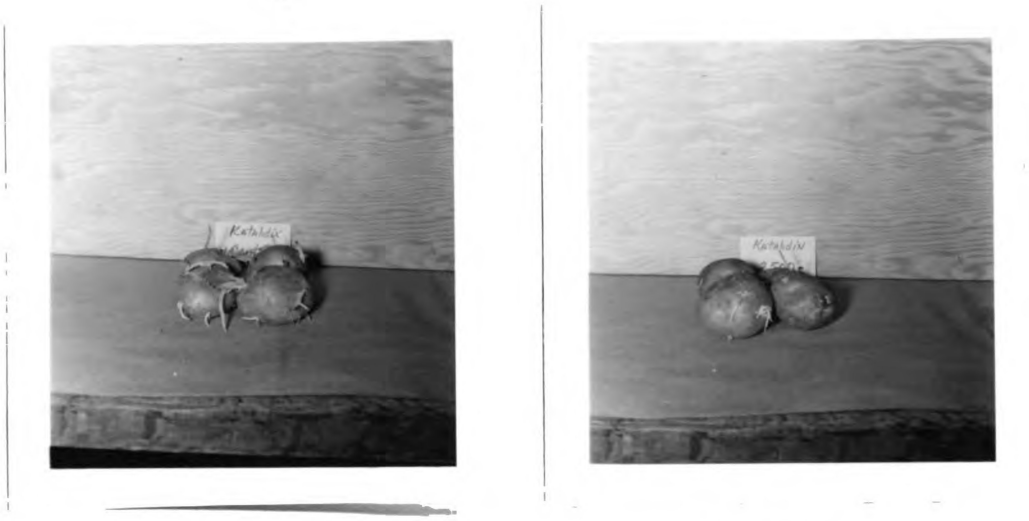


Figure 17: Total weight lost of irradiated Sebago tubers, expressed as percent of original weight.



Control

2,500 rep

5,000 rep

10,000 rep

Figure 18: Effect of increasing dosages of cathode ray irradiation on sprouting of Katahdin after four months storage at 44 degrees F. and 92 percent relative humidity. Irradiated March, 1958.

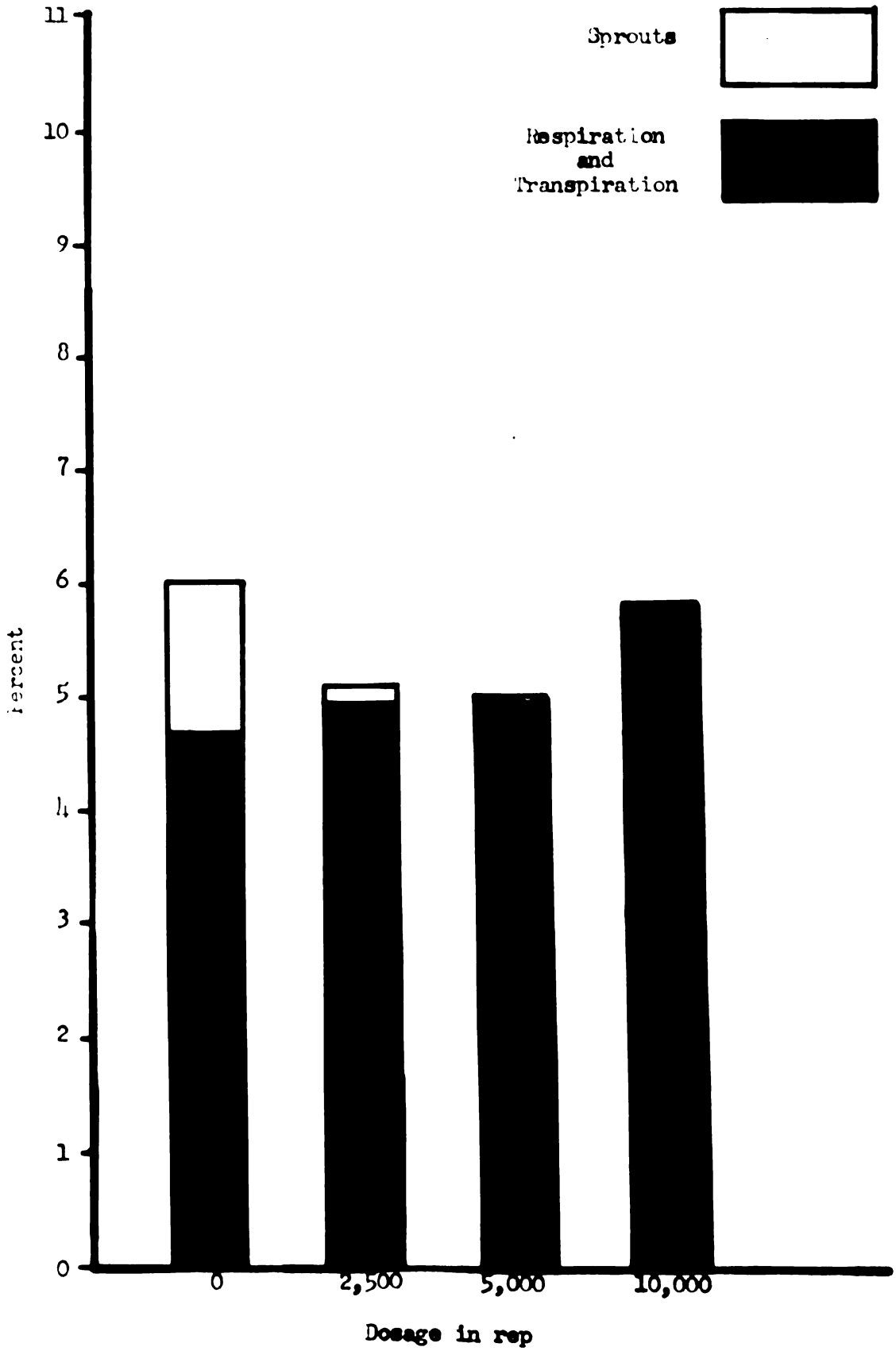


Figure 19: Total weight lost of irradiated Katahdin tubers, expressed as percent of original weight.

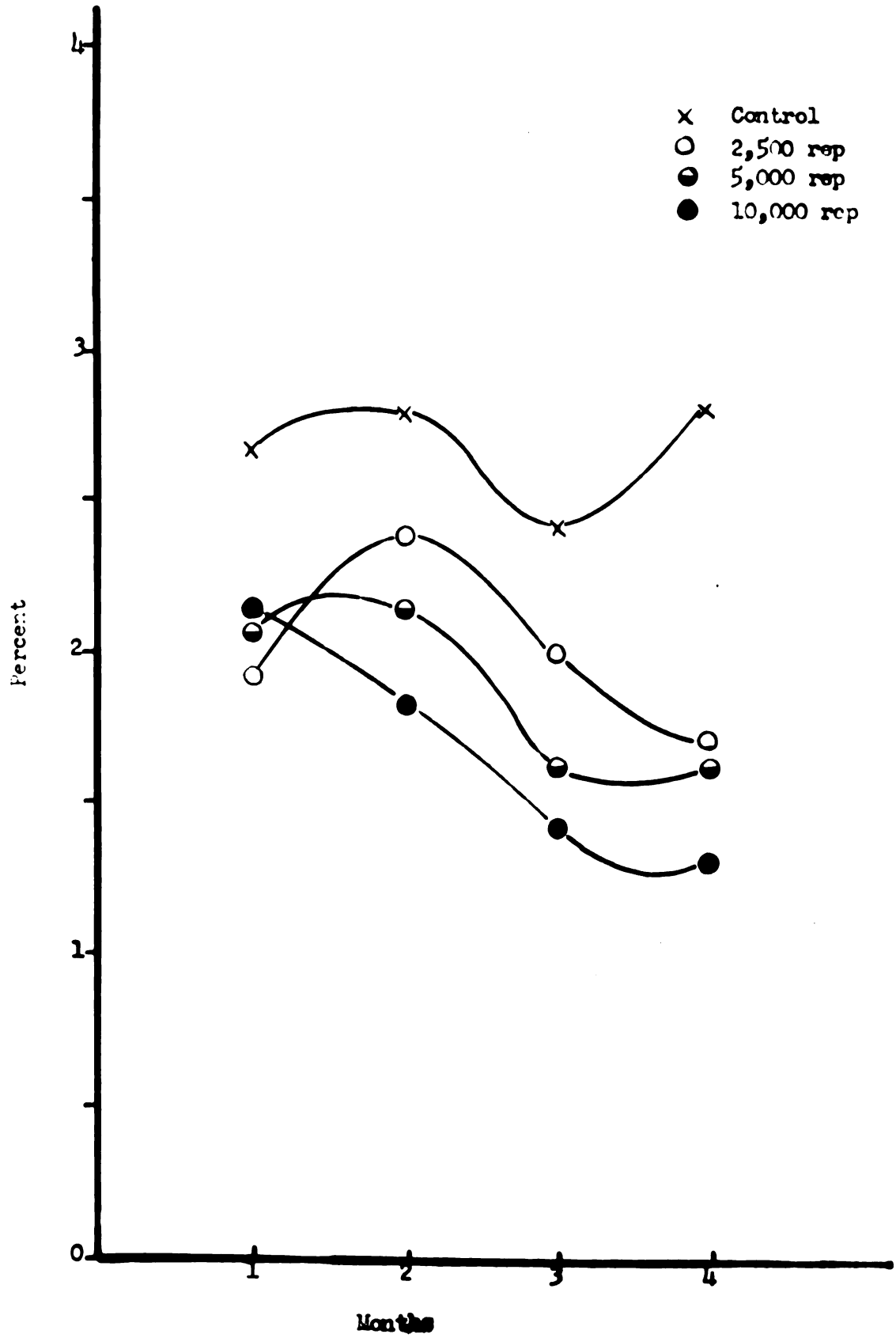


Figure 20: Rate of weight loss per month as affected by cathode ray irradiation. Expressed as percentage. Russet Rural var.

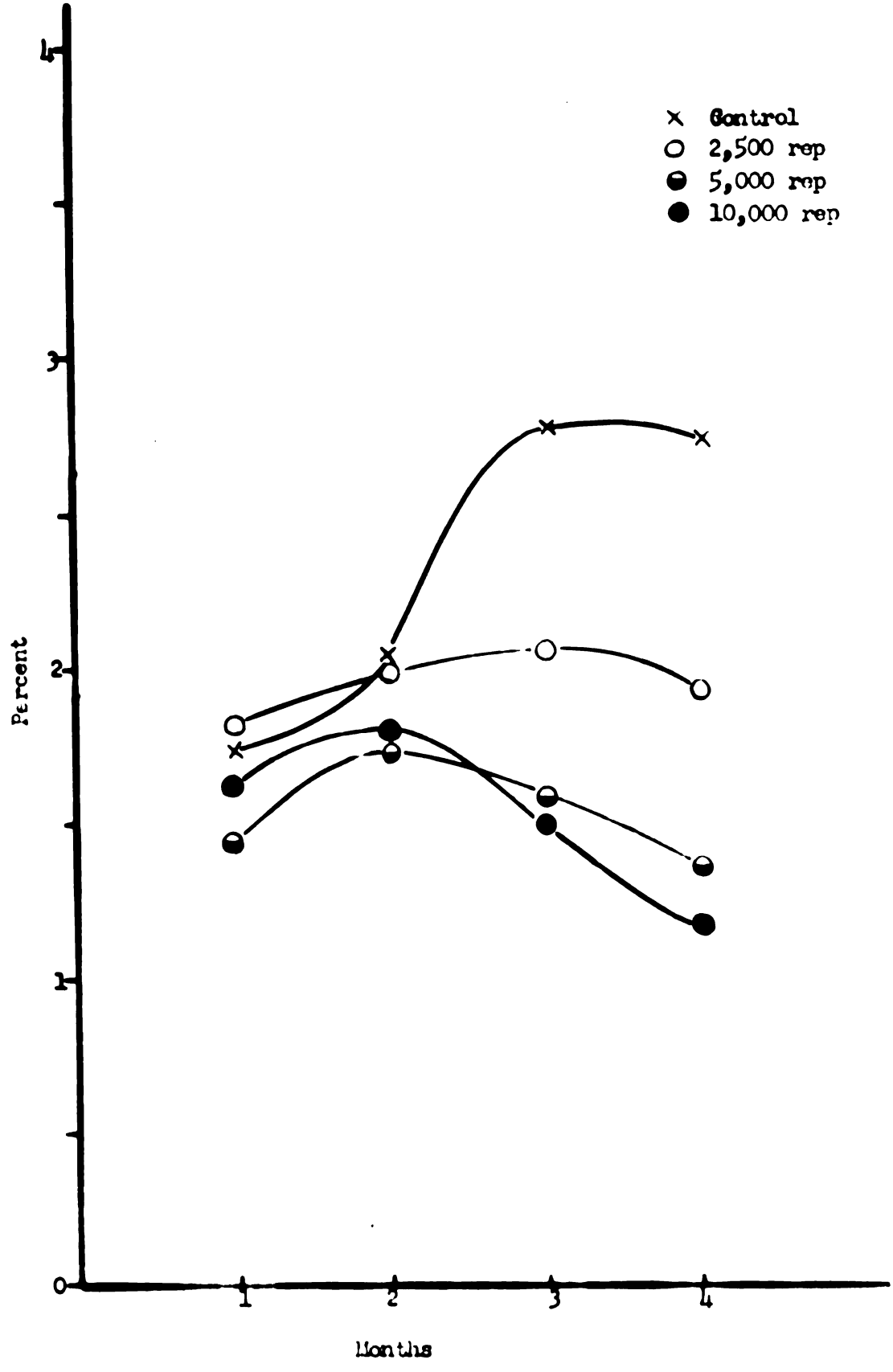


Figure 21: Rate of weight loss per month as affected by cathode ray irradiation. Expressed as percentage. Tobago var.

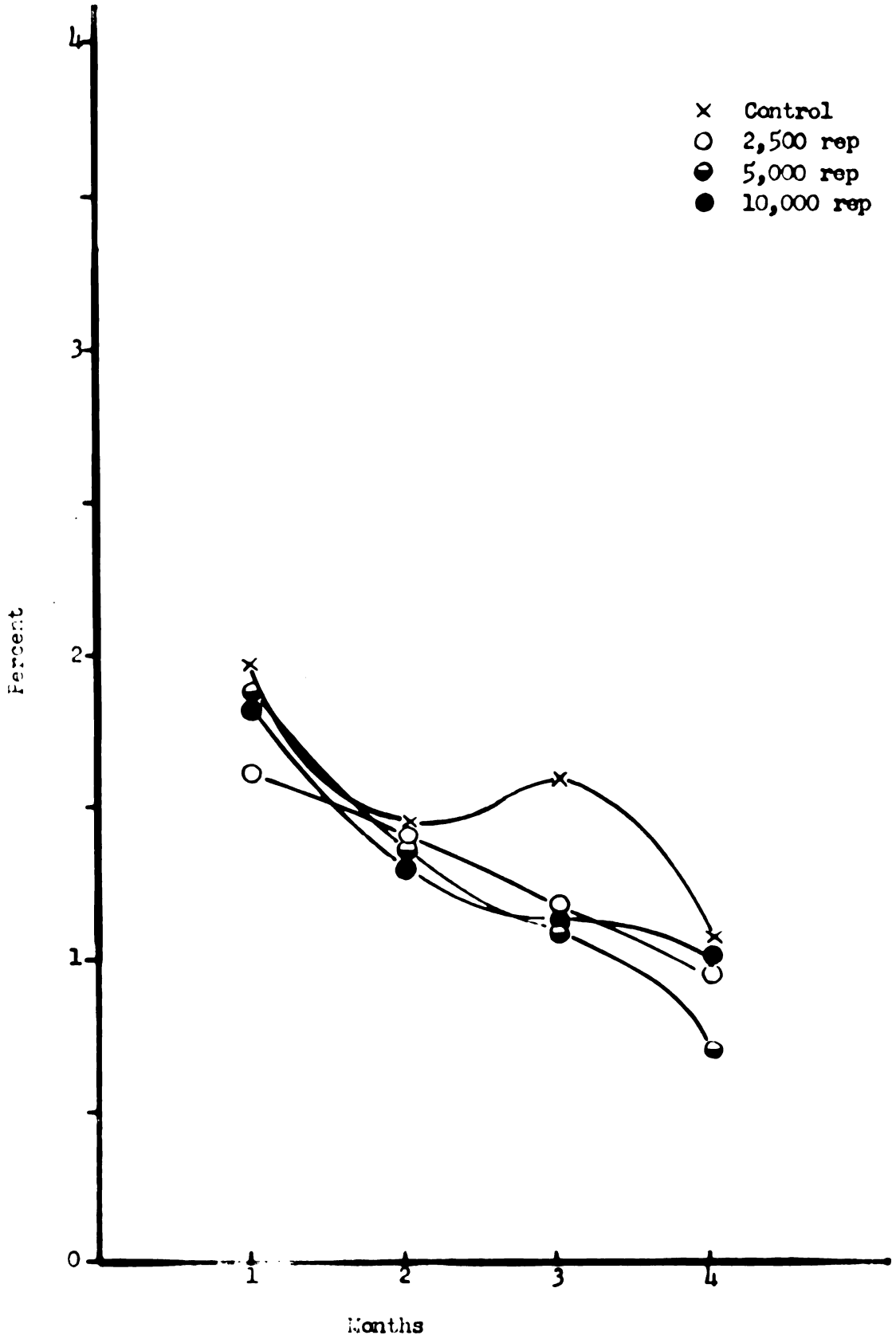


Figure 22: Rate of weight loss per month as affected by cathode ray irradiation. Expressed as percentage. Katahdin var.

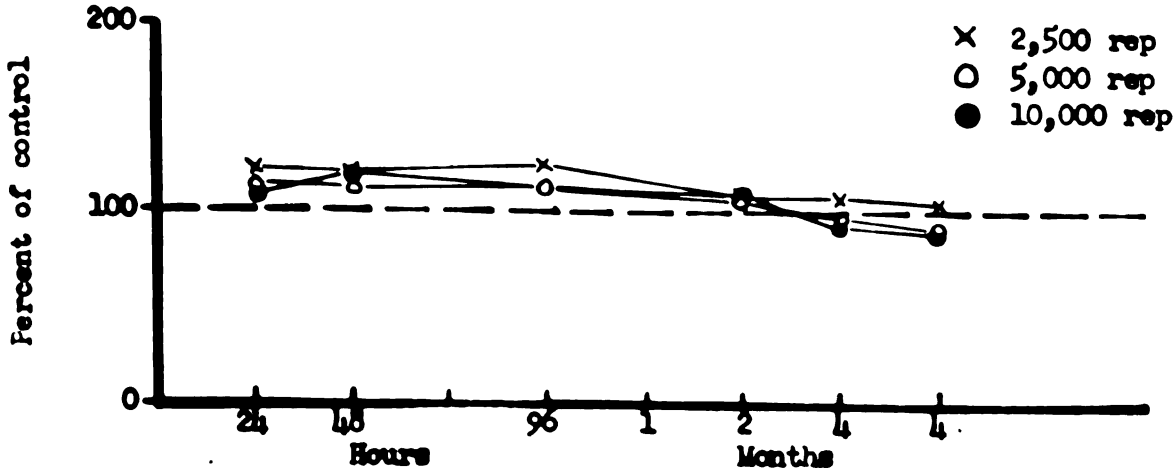


Figure 23: Effect of cathode ray irradiation on rate of oxygen consumption of whole Russet Rural tubers. Expressed as percent of control.

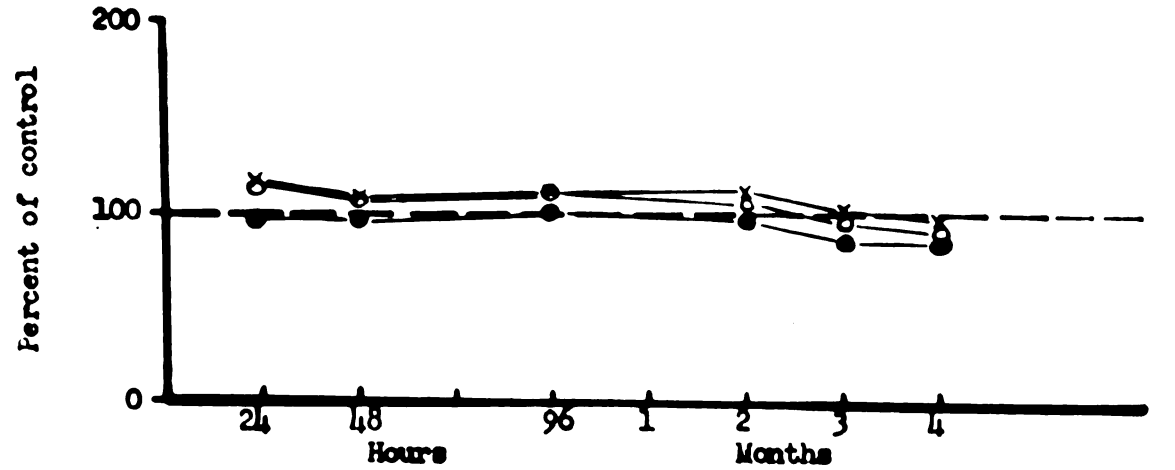


Figure 24: Effect of cathode ray irradiation on rate of oxygen consumption of whole Sebago tubers. Expressed as percent of control.

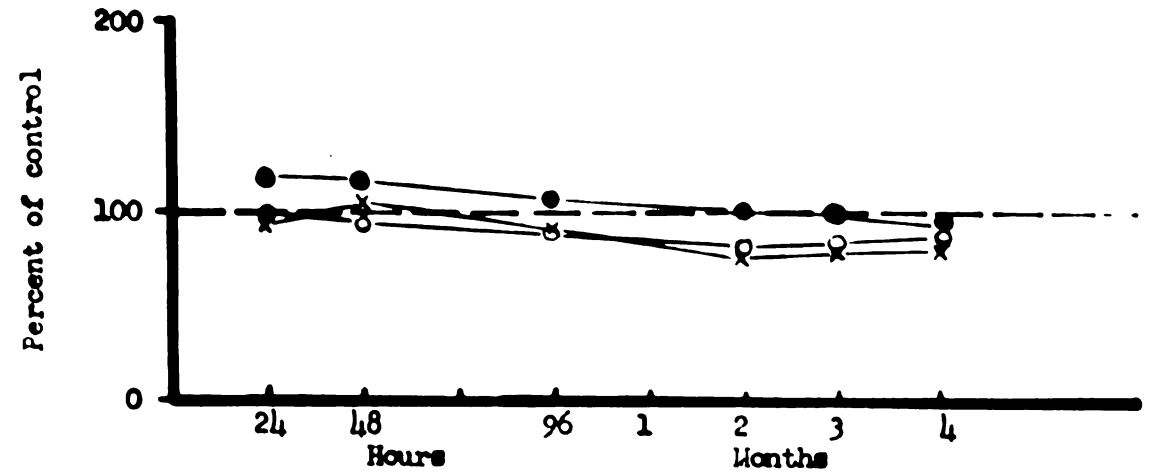


Figure 25: Effect of cathode ray irradiation on rate of oxygen consumption of whole Katahdin tubers. Expressed as percent of control.

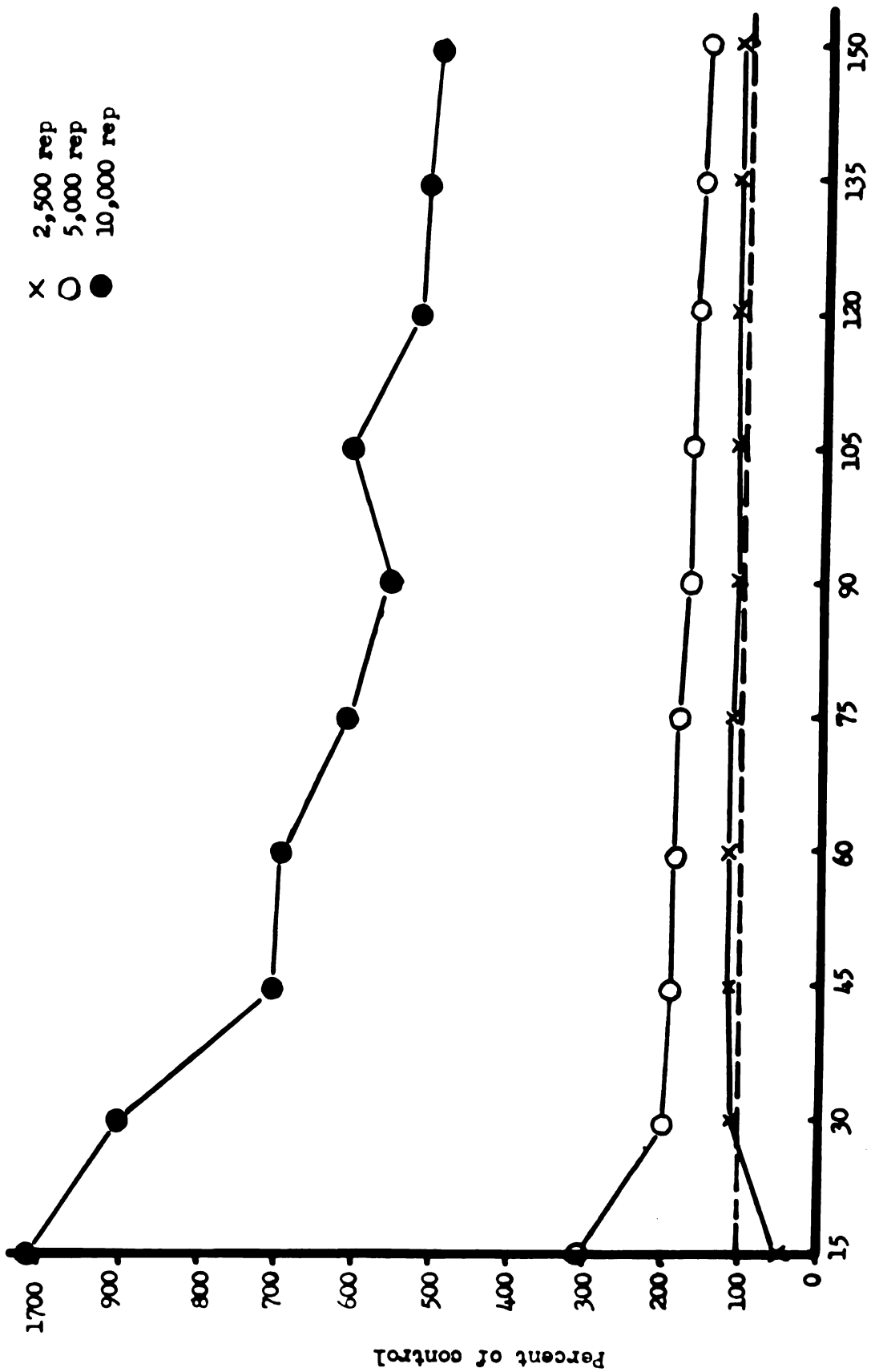


Figure 25: Effect of cathode ray irradiation on oxygen consumption of external tissue slices of Sabago var.

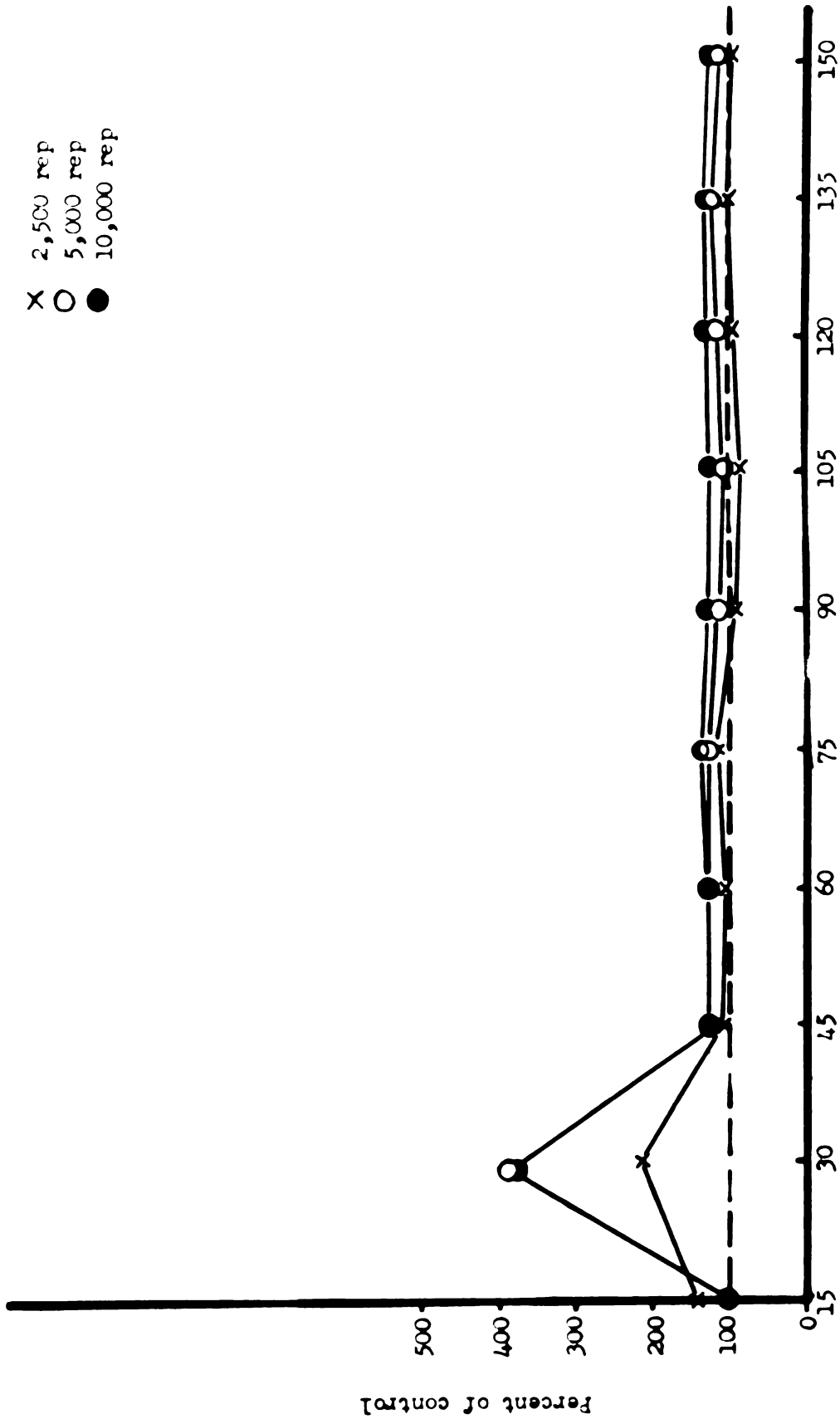


Figure 26: Effect of cathode ray irradiation on oxygen consumption of internal tissue slices of Sebago var.

Table 1: Respiration rates (mg. O2/100 g. fresh weight/hour) of three varieties of whole potatoes irradiated with cathode rays early and late in the storage season. Measurements made with Haldane gas analysis apparatus.

Variety and Treatment (rep)	24 hours	48 hours	96 hours	1 month	2 month	3 month	4 month
Early (EXP. I)							
Russet Rural							
Control	0.77	0.37	0.62	0.31	1.49	3.80	4.14
2,500	0.97	2.78	2.18	1.32	2.99	3.70	3.85
5,000	1.13	2.71	2.48	1.46	2.91	3.06	3.29
10,000	1.20	3.00	2.76	1.49	3.00	3.29	3.26
Mean	1.02	2.22	2.01	1.15	2.59	3.46	3.63
Sebago							
Control	1.28	0.90	0.51	0.62	1.37	4.40	5.34
2,500	2.96	2.85	2.61	3.84	2.96	3.14	3.28
5,000	3.39	2.93	3.18	3.67	2.64	3.23	3.20
10,000	3.61	3.61	3.21	0.96	3.44	3.24	3.47
Mean	2.81	2.57	2.38	2.27	2.60	3.50	3.82
Katahdin							
Control	0.43	0.57	0.57	0.58	1.65	3.68	3.94
2,500	2.66	2.53	2.66	3.44	1.40	3.12	3.32
5,000	2.14	2.48	2.93	2.85	0.90	2.80	2.98
10,000	2.90	3.51	2.66	0.73	1.27	2.92	3.28
Mean	2.03	2.27	2.21	1.90	1.31	3.13	3.38
Late(EXP. II)							
Russet Rural							
Control	3.29	3.16	3.16		3.10	3.66	3.71
2,500	3.86	3.71	3.96		3.52	4.02	3.98
5,000	3.66	3.66	3.56		3.52	3.62	3.64
10,000	3.55	3.70	3.41		3.52	3.62	3.71
Mean	3.59	3.55	3.52		3.41	3.73	3.76
Sebago							
Control	3.06	3.32	3.06		3.00	3.48	3.52
2,500	3.64	3.64	3.50		3.58	3.70	3.69
5,000	3.67	3.52	3.52		3.24	3.42	3.47
10,000	2.98	3.23	3.11		2.90	2.96	3.00
Mean	3.33	3.42	3.29		3.18	3.39	3.42
Katahdin							
Control	3.09	3.22	3.48		3.48	3.87	3.90
2,500	2.89	3.37	3.13		2.68	3.20	3.25
5,000	3.05	3.05	3.16		2.56	3.07	3.04
10,000	3.91	3.91	3.77		3.50	3.86	3.82
Mean	3.23	3.38	3.38		3.05	3.50	3.50

SUMMARY AND DISCUSSION

It has been shown that cathode ray irradiation up to 10,000 rep considerably decreased the sprouting of three varieties of potatoes. The mechanism of this inhibition is not known, although there is evidence to show that it is a delay rather than complete inhibition. At the end of Experiment I, the de-sprouted tubers were further stored at 62 degrees F. for twelve weeks. A perfunctory examination at that time revealed that a large percentage of the tubers, regardless of variety or irradiation dose, had sprouts up to 15 inches in length.

The data on weight loss indicate that doses at or near the minimum for sprout inhibition caused a decrease in the total weight lost. However, although the response to weight loss exclusive of sprouts depended upon the time between harvest and irradiation, and upon variety. In general the monthly rate of weight loss was less with the treated tubers than with the controls. During Experiment I the irradicated tubers lost a greater percentage of their weight the first month than the controls. However, during the ensuing three months the rate was less than that of the control. In Experiment II the rate of weight loss was less than the controls during the four month period.

In comparing the rate of oxygen consumption with the rate of weight loss it would seem that during the first two months the majority of the weight lost was due to accelerated respiration, as measured by oxygen consumption. Heiligman (1957) noted that a similar rise caused by gamma irradiation may be associated with a rise in sugar content. As the surplus sugar is used up the rate of respiration returns to normal.

It is possible that a similar explanation may be valid for the results obtained in this experiment. The data on oxygen consumption of the potatoes in Experiment II is difficult to explain, although the results of Brownell et al. are similar and of the same magnitude. Two possible explanations of the lower oxygen consumption at the later date are that the respiration mechanism was less susceptible to radiation stimulation late in the storage season; or that the cell walls offered greater resistance to the penetration of electrons at this time.

CONCLUSIONS

1) Cathode-ray irradiation affects sprouting, weight loss, and oxygen consumption of potatoes much the same as gamma irradiation. Irradiation inhibited sprouting of all three varieties when applied either early or late in the storage season. Weight loss exclusive of sprouting was dependent on variety and time of irradiation. Oxygen consumption increased shortly after irradiation followed by a gradual decline until at the third and fourth month the rate was the same or slightly less than the control.

2) The optimum sprout-inhibiting dose is between 5,000 rep and 10,000 rep, varying with the variety and time of time of irradiation.

3) Cathode-ray irradiation produces no permanent physiological changes between 2,500 rep and 10,000 rep, as measured by oxygen consumption.

4) It would appear that cathode-ray irradiation delays rather than completely inhibits sprouting.

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