# Reports and Letters

## Radiation Sensitivity of Dormant and Germinating Barley Seeds

Recent investigations (*1*) have indicated that when seeds are irradiated with x-rays, some are severely damaged but others are only very slightly damaged. However, when seeds are irradiated with fast or thermal neutrons, all are damaged to a similar extent. This phenomenon indicates a qualitative difference between x-ray and neutron irradiation. A possible explanation of this phenomenon is that the seeds are actually not all alike but differ in some characteristics that are very important for their response to x-rays but unimportant for their response to neutrons. Our experiments were undertaken to test this hypothesis and to elucidate the factors responsible for radiosensitivity of seeds. (*2*)

One obvious factor that might be considered is the water content. Accordingly, barley seeds were presoaked on wet blotters for times up to 24 hr at 22°C prior to irradiation. The water content of the seeds was determined at the time of irradiation. Neutron exposures were performed in the thermal column of the Brookhaven reactor (flux approximately $9 \times 10^8 n_{\text{th}}/\text{cm}^2$ sec; cadmium ratio 5000:1; gamma contamination approximately 100 r/hr). X-ray exposures were made at 250 kv, 30 ma, with 1-mm Al filtration. The intensity was about 800 r/min. After irradiation, the seeds were planted in flats, and the height of the seedlings was measured as a function of time. In general, the height at 14 days was taken as a measure of the extent of injury.

Results of a representative series are shown in Fig. 1. The seeds were exposed

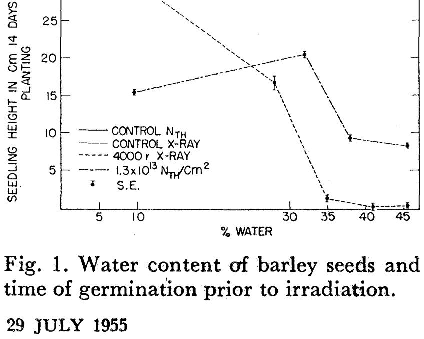


Fig. 1. Water content of barley seeds and time of germination prior to irradiation.

to either 4000 r of x-rays or $1.3 \times 10^{13}$ $n/\text{cm}^2$. For seeds exposed to x-rays, the sensitivity is extremely dependent upon water content, but the sensitivity of seeds exposed to neutrons is comparatively independent of water content over a wide range. Indeed, after 6 hr of germination, seeds are less sensitive to neutron irradiation than dormant unsoaked seeds are.

The interpretation of these results is not at once clear, but one obvious possibility presents itself. Soaking the seeds changed their physiological state, as was shown by the increased metabolic activity and germination. Thus, it seems reasonable to assume that these effects are caused primarily by changes in the physiological state of the seeds. This influence of physiological state was known from earlier x-ray experiments (*3*). However, the influence on neutron sensitivity was not clear, and another series of experiments was undertaken, namely, soaking seeds at 0°C in order to increase their water content but to limit corresponding changes in physiological state. To date, the results are only preliminary, because facilities for irradiation at different temperatures in the thermal column are not yet complete. However, they clearly show that increasing the water content at low temperature has less effect on x-ray sensitivity than it has at high temperature. Furthermore, seeds exposed to thermal neutrons after low-temperature soaking do not respond in ways markedly different from those soaked at room temperature. Thus, it seems that water content per se, if it is important in determining radiosensitivity, plays a role that is not immediately evident.

The biological action of x-rays appears to be more dependent on the physiological condition of the irradiated object than that of neutrons is; therefore, it is reasonable to explain the lower uniformity of damage to individual seeds as related to slight variations in metabolic stage.

The reason for the differences between the actions of x-rays and thermal neutrons is not readily apparent. Certain dissimilarities in their actions can be explained by their different chances to produce biological events as well as by their different biological efficiencies. Protons and alpha particles, both of which are densely ionizing, are the principal means of energy dissipation characteristic for the capture reactions of thermal neutrons in living tissue (*4*). Dense ionization is highly efficient when more spatially concentrated energy is needed, but it is inefficiently utilized when little energy is necessary. On the other hand, the ionization along the electron tracks produced by x-rays is sparse and unevenly distributed, although for a given amount of energy absorbed there is a more uniform distribution of ionization throughout the cell. Sparse ionization has a high efficiency only for events requiring small amounts of energy (*5*). A decrease in the threshold energy required for the events should increase the relative efficiency of x-rays; the reverse should be true for neutrons. From this knowledge, it is logical to interpret the increased relative efficiency of x-rays on presoaked seeds as the result of a reduction in the amount of energy necessary to produce the biological events. This relationship of radiation damage to the structural stability of cell components has also been presented recently in a similar way by Caldecott (*6*).

In summary, striking differences in the relative sensitivity of seeds to x-rays and thermal neutrons were observed. These differences were considered to be associated with changes in physiological state which differentially influence the relative efficiency of the two radiations.

Calvin F. Konzak
*Biology Department, Brookhaven National Laboratory, Upton, New York*

#### References and Notes

1. J. MacKey, *Hereditas* **37**, 421 (1951); R. S. Caldecott *et al.*, *Genetics* **39**, 240 (1954).
2. This research was carried out at Brookhaven National Laboratory under the auspices of the U.S. Atomic Energy Commission.
3. E. Wertz, *Strahlentherapie* **67**, 307, 536, 700 (1940); **68**, 136, 287 (1940); K. Sax, *Proc. Natl. Acad. Sci.* (*U.S.*) **25**, 225 (1939).
4. J. W. Schmidt and E. F. Frolik, *Univ. of Nebraska Research Bull.* 167 (1951).
5. L. H. Gray, *Radiation Research* **1**, 19 (1954).
6. R. S. Caldecott, *Radiation Research*, in press.

14 March 1955

## Methylamine Complexes of Yttrium Chloride

In a recent study it was found that methylamine forms addition complexes with the anhydrous rare-earth chlorides of lanthanum, cerium (III), praseodymium, neodymium, samarium, and gadolinium (*1*). The composition of these complexes can be designated as $RE(\text{CH}_3\text{NH}_2)_n\text{Cl}_3$, where $n$ has values of 1 to 5. Since yttrium salts are chemically similar to the corresponding rare-earth compounds, the complexes with methylamine should be analogous; to a certain extent, this was found to be the case.