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 $9 \times 10^8 n_{\mathrm{th}}/\mathrm{cm}^2$ 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 to either 4000 r of x-rays or 1.3×10^{13} n/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.

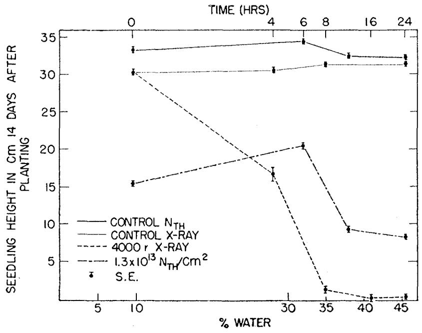

Fig. 1. Water content of barley seeds and time of germination prior to irradiation.

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.

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References and Notes

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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 $RE(CH_3NH_2)_nCl_3$, 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.

The reaction between methylamine and yttrium chloride was studied by the method of isobaric thermal decomposition curves. This method consisted of the formation of the higher methylamine complex at 0°C, after which the complex was subjected to thermal decomposition at a constant pressure. The apparatus used has been previously described (*2*). The anhydrous yttrium chloride was prepared by heating the hexahydrate in a hydrogen chloride atmosphere with the following temperature stops: 4 hr at 90°C, 1 hr at 180°C, and 2 hr at 400°C (*3*). The resulting product was analyzed and found to be free of water. The preparation and purification of the methylamine has been described by Kenner and Felsing (*4*).

The thermal decomposition curve is shown in Fig. 1. According to the phase rule, a reversible phase that is stable over a specific temperature range can be considered a chemical compound. The curve was reproducible and reversible within an experimental error of ±0.5 percent. Four compounds can be identified from the curve: $Y(CH_3NH_2)_4Cl_3$, $Y(CH_3NH_2)_3Cl_3$, $Y(CH_2NH_2)_2Cl_3$, and $Y(CH_3NH_2)Cl_3$. The decomposition temperatures are given in Table 1.

It is interesting to note that a complex with five methylamine molecules was not found, as was the case with the rare-earth complexes. Even at 0°C, this complex could not be detected. It is obvious that the yttrium chloride complexes are less stable. According to ionic radii considerations, the smaller ion should form the more stable complex; therefore, the yttrium ion (1.06 A), being smaller than

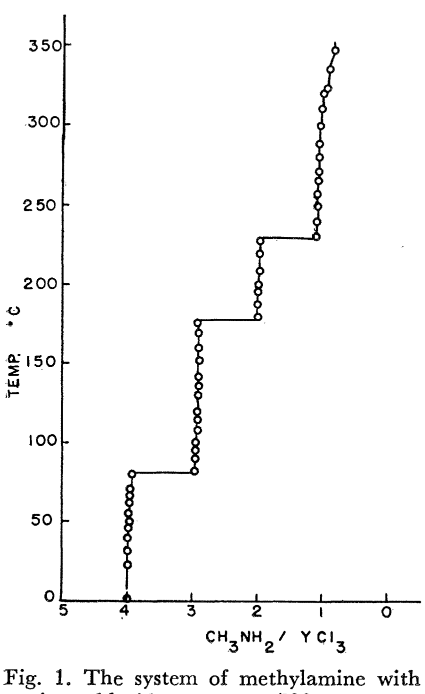

Fig. 1. The system of methylamine with yttrium chloride; pressure, 700 mm.

Table 1. Decomposition temperatures of the methylamine complexes of yttrium chloride

Transition	Temperature (°C)
$Y(CH_3NH_2)_4Cl_3 \rightarrow Y(CH_3NH_2)_3Cl_3 + CH_3NH_2$	82
$Y(CH_3NH_2)_3Cl_3 \rightarrow Y(CH_3NH_2)_2Cl_3 + CH_3NH_2$	180
$Y(CH_3NH_2)_2Cl_3 \rightarrow Y(CH_3NH_2)Cl_3 + CH_3NH_2$	232
$Y(CH_3NH_2)Cl_3 \rightarrow YCl_3 + CH_3NH_2$	> 360

the rare-earth ions that were studied (122 to 1.11 A), should be more stable. Apparently other factors that make the influence of the smaller ion size of lesser importance must be present.

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Frenquel Corrects Certain Cerebral Electrographic Changes

Lysergic acid diethylamide (LSD-25), an alkaloid derived from ergot, produces in human subjects mental disturbances consisting of visual hallucinations and other psychotic symptoms (*1*). This phenomenon has been widely investigated because the psychotic symptoms evoked by LSD-25 are similar to those of schizophrenic patients. Mescaline is another alkaloid long known to produce hallucinations and other psychological and somatic changes like those caused by LSD-25 (*2*). LSD-25 induces, in both experimental animals (*3*) and human beings (*4*), alterations of the electric activity of the brain, consisting of the disappearance or diminution of the slower waves, an increase in the average frequency and of fast low-voltage activity as well as a general diminution of voltage resulting in a flattening of the record.

We studied the effect of mescaline on the electric activity of the rabbit brain and found that it introduces changes that are practically identical with those resulting from LSD-25. It is interesting to note that there is a similarity in the alterations of the electroencephalogram (EEG) induced by these hallucinogenic substances and the records often obtained from schizophrenic patients (*5*). In fact, the choppy rhythm that Davis found in schizophrenic patients consists of low-voltage fast activity accompanied by a poor organization of the alpha rhythm.

The brain electric activity of the curarized, unanesthetized rabbit (the preparation used in the present studies) consists of two fundamental patterns: one, which is seen when the rabbit is undisturbed and resting quietly, consists of slow high-voltage waves and 14-cy/sec spindles; the other, observed when the animal is alerted by a sensory stimulation, reveals fast low-voltage cortical activity with a 4- to 6-cy/sec thalamic rhythm (*6*). This occurs when a neuronal system (mesodiencephalic activating system), which regulates diffusely the electric activity of the brain (*6*), is set into operation.

LSD-25 (10 to 15 µg/kg) and mescaline (10 to 20 mg/kg) induce a change of the electric activity of the brain, consisting in the first place in the elimination of the slow waves and the spindles typical of the resting pattern and, in the second place, in the persistent presence of fast low-voltage activity and the 4- to 6-cy/sec thalamic rhythm, practically identical with the picture that is seen in the alert status (Fig. 1).

Recently Fabing (*7*) reported that the psychotic symptomatology produced in human subjects with hallucinogenic amounts of LSD-25 disappeared after the administration of alpha-4-piperidyl benzhydrol hydrochloride (Frenquel) (*8*). The latter is a new nonhypnotic drug that renders animals less active and in human subjects produces promising results in the management of abnormal mental conditions (*9*).

In our experiments on the rabbit we administered alpha-4-piperidyl benzhydrol hydrochloride intravenously in doses between 8 and 24 mg/kg to animals that had received amounts of LSD-25 or of mescaline sufficient to cause the afore-described permanently alert change of

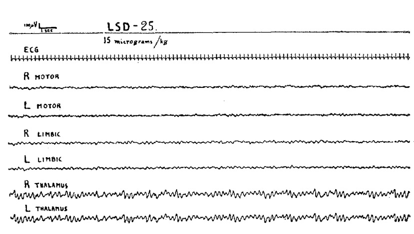

Fig. 1. Effect of LSD-25 on the cerebral electric activity of the rabbit. Notice the low-voltage fast activity in the motor cortex and the thalamic 4- to 6-cy/sec rhythm. Note also the absence of high-voltage slow waves and of spindles. Six monopolar leads from different cerebral structures, as indicated in the figure. Top tracing: electrocardiogram.