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Radiosensitivity Factors in Oat Seeds: Dormancy, Water, and Development

Germinating seeds have been reported to be more sensitive to irradiation and to have exhibited higher mutation frequencies than dormant seeds (*1*). This has been variously related to three major factors—namely, water content (high or low), actively growing tissue, and mitotic activities (*2*). The role of each factor has been difficult to evaluate because the factors are interdependent and function together in processes of growth. The study described here (*3*) attempted a comparative experimental test in which one factor played its role as an independent variable and in which the other two were held constant as far as this could be accomplished with living biological entities.

Radiosensitivities of two lots of seed were compared. Both lots were of the same stock and were in dormant state, with moisture content approximately equal. One differed from the other chiefly in the structural and other developments, including those of nuclei, brought about by a period of preactivation or partial germination. One lot was ungerminated and dormant, with 13.1 percent moisture. The other was partially germinated and dormant; it was prepared by soaking ungerminated seeds in running water for 20 hours at 29°C (*4*), then air-drying to 12.6 percent moisture to return them to dormancy. These seeds became 7.5 percent larger but slightly lighter than the ungerminated seeds.

Germination of both lots prior to irradiation was normal, and the percentage germination was equal (95.1), indicating that activation and subsequent desiccation did not alter adversely viability or vigor.

The irradiations were in replications with x-rays (25,000 r) and with thermal neutrons for 6 hours (flux 6.2×10^8 N_{th}/cm^2 sec.) (*5*).

Irradiation effects were measured in the laboratory by germinating the seeds under uniform conditions of temperature and moisture and then recording inhibition and stunting of both roots and shoots (leaves and coleoptiles) after 7 days. Lethal effects were judged by the number of nongerminating seeds in excess of that for the checks; inhibition and stunting were judged by reduction in number and length of radicles, by absence of shoots, and by length of shoots. Three replicated trials at room temperature and one at constant temperature of 20°C gave similar results (2400 irradiated seeds and 1200 nonirradiated checks were studied with a total of 72 replications of 50 seeds each).

Additional seed lots were soaked in 2-percent NaCl for 2 hours immediately after water-soaking and prior to desiccation and irradiation. The results (Table 1) were as follows.

1) Partially germinated dormant seeds exhibited greater sensitivity to both x-rays and thermal neutrons than ungerminated seeds of comparable moisture content. The average seedling size of x-rayed, partially germinated seeds was 15.4 percent of normal, whereas that of ungerminated was 34.5 percent of normal. The greatest lethal effects were caused by x-rays on partially germinated seeds.

2) Radiation effects of x-rays were greater than those of thermal neutrons (for the doses used) for both seed lots, as has been previously reported for germinating seeds.

3) Roots suffered greater inhibition from irradiation than leaves. In partially germinated seeds, they were shorter than the leaves, while in the ungerminated checks the reverse was true. This difference in response of the two main organs may be attributed either to inherent cell differences in radiosensitivity or, more probably, to the more advanced development of the roots, indicating that even slight differences in growth rates may be reflected in marked differences in radiosensitivity.

4) Both irradiated and nonirradiated populations showed great variability in rate of development and size of roots and leaves. This variability, as statistically expressed by a coefficient of variability (percentage), seems to be correlated with the amount of injury sustained by each irradiated population, as follows: x-rayed, partially germinated, 115 percent; x-rayed, ungerminated, 75 percent; thermal-neutron treated, 42 percent (nonirradiated, 36 percent). The coefficient of variability for all irradiated radicles was 92 percent; for all irradiated shoots, 64 percent.

Within nonirradiated seeds, root elongation during the first 48 hours ranged from 0 to 8 mm. Roots developed twice as fast as shoots in the early hours of germination. These differences may account for the difference in radiation effects within a given population. Activated, salt-treated seeds showed less injury than nontreated seeds, possibly because the diffusing salt, upon reaching the embryo, slowed down germination (*6*).

It may be concluded, therefore, that the increased radiosensitivity of partially germinated, dormant seeds over ungerminated seeds was induced by a factor or factors other than moisture content. Germination induces the synthesis of many enzyme systems, and it is assumed that the partially germinated dormant seeds had a higher enzyme complement than the ungerminated seeds. However, at the time of irradiation the enzyme activities of both kinds of seed were at their minimum, because of the low moisture content

Table 1. Effects of irradiation on ungerminated and partially germinated, dormant oat seeds. (Germination for 7 days at 20°C.)

Kinds of dormant seeds and irradiations	Nongerminating seeds after irradiation (%)	Seedlings with no radicles* (%)	Shoots		Radicles	
			Average length (mm)	Standard error	Average length (mm)	Standard error
Partially germinated, x-rays	12	12	8	0.8	6	1.0
Ungerminated, x-rays	8	3	20	0.9	15	1.3
Partially germinated, thermal neutrons	7	1	35	0.8	20	0.9
Ungerminated, thermal neutrons	7	1	48	1.1	26	1.2
Partially germinated, no irradiation	5	0	56	1.2	67	2.3
Ungerminated, no irradiation	5	0	53	1.4	64	2.4

* Seedlings with shoots only, the radicles having been completely inhibited.

and the cessation of all growth. The increased radiosensitivity appears to be chiefly associated, then, with the advanced developments induced in the partially germinated, dormant seeds. These developments may be identified with certain chemical and structural changes within rapidly dividing cells—namely, the initiation of nuclear divisions and the exposure to irradiation of enlarged and possibly oversensitized chromosomes, just prior to, or during mitotic activities.

Inasmuch as the water content of both lots of seeds was about the same, it would seem that increased seedling injury in the case of partially germinated, dormant seeds is related primarily to direct absorption of energy from ionizing radiations rather than to indirect chemical action of active radicles produced in the presence of water.

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3. This work is a part of a study to determine more effective ways of utilizing radiation techniques in connection with breeding oats for disease resistance and other qualities.
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5. I am indebted to Seymour Shapiro of the Brookhaven National Laboratory for performing the irradiations.
6. The role of salts, oxygen, temperature, and other factors besides water on lowering or hastening the initial rate of development should be taken into consideration in interpreting radiation effects on biological material.

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Ability of Thais haemostoma to Regenerate Its Drilling Mechanism

The odontophoral process of the prosobranch gastropods is situated at the distal end of the proboscis, which is essentially a very extensible and maneuverable tube extending from the esophageal region, with the mouth at the end. The odontophore consists of a cartilaginous carriage, which licks back and forth while the radular band moves back and forth over it like a belt over a pulley (*1, 2*). Possibly the radula can also be held stationary at times, with the sole movement being made by the cartilaginous carriage. This may account for the differences in observations made by some famous zoologists in the past century (*1*). With its attendant muscles and nerves, the odontophore is a very complicated mechanism (*2*) and efficiently operates in drilling as if it were a small rotary drum covered with spikes (*1*).

Hundreds and possibly thousands of species of predatory gastropods drill holes through the shells of other mollusks and extract the meat. It is generally stated that this ability is possessed only by the Naticidae and Muricidae. It should be noted, however, that the Thaisidae have been separated from the Muricidae. In addition, Moore (*3*) has shown that three species of the Cassidae bore through the calcareous tests of sea urchins and sand dollars.

The odontophore is certainly mechanically efficient, but whether it functions in this manner alone (*4*) or is sometimes assisted by acids or enzymes is not yet settled (*5*). Furthermore, *Thais haemostoma,* the Gulf oyster borer, which is at times a very serious oyster pest, can open oysters without leaving any sign of shell damage whatsoever. This raises the question of whether the animal makes use of some paralytic agent.

In an attempt to answer this question, we cut off the proboscis of several *Thais* with a razor blade. This was done after the hungry animals had been induced to extend the proboscis through a small hole in a plate of plastic to reach a piece of oyster meat placed to one side. The cutting movement had to be swift, for the proboscis is very sensitive and can be retracted with the speed of a rubber band. It was noted that "conchs" that had the proboscis cut cleanly survived, while those suffering jagged cuts did not. Only the distal portion of the proboscis containing the odontophore was cut off. These were preserved in formalin. The supposition was that these "aradulate" gastropods might open oysters by use of a paralytic agent, if they possessed one.

The planned experiment was a complete failure, but the results were nonetheless startling. Within 3 weeks, the surviving gastropods all regenerated the complete odontophoral process, as good as new, and without abnormalities as far as we can determine. The odontophore, consisting as it does of muscle, nerves, cartilage, and chitinous teeth in a band, which undergo a complex but coordinated set of movements, may well be the most complicated organ any animal is able to regenerate. The complexity of the odontophore has been shown best by the detailed anatomical studies of Carriker (*2*) on *Urosalpinx.* The anatomy of *Thais* has not been described, but it is very similar.

The morphogenetic processes involved in the regeneration of this complicated organ may or may not yield easily to analysis. The apparatus lies in a tube, but it probably will not be extruded by the animals while healing. In any case, some interesting questions are raised and other workers may wish to take advantage of this type of material.

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New Evidence for Reversal of the Geomagnetic Field Near the Pliocene-Pleistocene Boundary

It has been shown (*1*) that, almost without exception, undisturbed Cenozoic lava flows are magnetized roughly in the direction of the present geomagnetic field or at 180° to this direction, termed normal (N) and reversed (R), respectively. There are two conflicting interpretations of how this thermoremanent magnetization was acquired.

1) The geomagnetic field has two stable configurations, those of an axial geocentric dipole of either polarity. Change from one polarity to the other happens in a time of the order of some thousands of years and occurs a number of times in the Cenozoic period, the last occasion being about the Pliocene-Pleistocene boundary. The total time during which the field was reversed in Cenozoic times appears to be roughly the same as that during which the field was normal.

2) In about 50 percent of the lava flows, the iron oxide minerals responsible for the magnetization possess the anomalous property of spontaneously reversing the magnetization acquired during the first stages of cooling below the Curie point. This occurs either during the final stages of cooling or slowly through the time between the eruption and the present day. In the former case, certain interactions between two lattice sites or two phases must be assumed; in the latter case, diffusion of ions between lattice sites or chemical changes or exsolution must be postulated.

No simple decisive test of these hypotheses has so far been proposed. Geologic time correlation is not sufficiently good to allow the magnetization of lava flows of the same age in different places to be compared, nor can any laboratory tests entirely exclude the possibility that the anomalous properties required for the second hypothesis were not pres-