Irradiated seeds

RISØ

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Contents
Seeds of a plant types irradiated with six radiation dosages for one experiment (ca. 40 seeds per bag).
The following types can be supplied: Barley, wheat, rape, flax and yellow mustard, either individually or as a set with all five plant types (set item no. 7791.20).

Purpose
The goal of the experiment is to show the effects of increasing radiation dosage on plants. Using several different types of plants it is possible to show that radiation effects are more severe for some plant types than for others.

TEACHER'S GUIDE

Regarding the materials provided
The material consists of six seed samples (one of the plant types listed below irradiated with six different radiation dosages). The seeds have been irradiated with gamma radiation from a Cobolt-60 source at the Risø Research Center in Denmark. The irradiated seeds are not themselves radioactive. The plants types shown in the table are available.

should occur when illumination is greatest. Avoid direct sunlight. The soil should be kept moist while the seeds germinate. If flower pots are used, it is important that they are watered uniformly.

It may be necessary to move the flower pots around several times a week to provide uniform light and temperature conditions.

Observations
If the temperature is around 22-23°C the results can be evaluated after 7-8 days. At ca. 20°C and 17°C the germination period will be extended by 5 or 8 days respectively.

One can see by direct examination that the height of the plants is reduced for increased radiation dosages. It will also be apparent that the different types of plants react differently to the increased dosages.

It is possible to get a more quantitative expression for the effects of radiation by measuring the plant heights. This can be done by clipping the plants flush with the soil surface and

Itemno.	Plant type	Chromosome (2n)	Radiation dosage Gy*					
7791.14	Yellow mustard	24	0	100	200	400	800	1600
7791.13	Flax	30	0	100	200	400	800	1600
7791.12	Rape	38	0	100	200	400	800	1600
7791.11	Wheat	42	0	100	200	400	800	1600
7791.10	Barley	14	0	100	200	400	800	1600

*) 1 Gy (gray) = 100 rad = 1 J/kg tissue (a measure of absorbed dose) 1 kilorad = 1000 rad = 10 Gy

STUDENTS' GUIDE

1st day: preparation, sowing and care
8th-15th day: observe the growth of the plants

Preparation, sowing and care
The seeds are sown in a mixture of soil and fine gravel in short rows in planting trays (0.5 - 1.0 cm between plants, 3 cm between rows). They can also be sown in flower pots (plant separation 1 - 1.5 cm) In either case the seeds should be covered with 0.5 - 1.0 cm fine gravel. The largest seeds should be sown the deepest.

After sowing the soil should be moistened. The seeds should be placed in a bright location (e.g. in a greenhouse or on a window sill) to germinate under approximately constant conditions of temperature and illumination. The temperature should be between 17 and 23°C. The highest temperatures

then measuring the height of each plant. Then the average height can be calculated (the height of an ungerminated seed can be set to zero).
The effects of the increased radiation dosage on each plant type can be seen directly from the average values for the plant heights.

The effects of the increased radiation dosage N on the five different types of plant are most easily seen by computing the height of each dosage result as a percentage of the unexposed material using the equation

$$\frac{\text{height for dosage N}}{\text{height for unexposed}} \times 100$$

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Record the values for the average plant heights in centimeters in a table such as the following:

Average plant height per plant type and radiation dosage							
Type		Radiation dosage in Gy					
		0	100	200	400	800	1600
Yellow mustard	cm pct.	 100					
Flax	cm pct.	 100					
Rape	cm pct.	 100					
Wheat	cm pct.	 100					
Barley	cm pct.	 100					

It is also helpful to get an impression of the different reactions from the five types of plants by plotting the percentage values from the table in a coordinate system. Use "plant height in % of unexposed" as the y-coordinate and "radiation dosage" as the x-coordinate. It is sometimes observed that yellow mustard exposed to a low dosage of radioactivity has a larger average height than unexposed material (growth stimulation). It turns out that this is a transient phenomenon which can not be put to advantage in plant culture.

THEORY BEHIND THE EXPERIMENT

The physiological and genetic effects of radiation

The physiological effect of radiation increases with increasing radiation dosage as shown by the reduction in plant height. The radiation effect is thus damage to the plants. The highest radiation dose can destroy most or all of the plants. However, by digging up the seeds one can see in the case of barley exposed to 800 and 1600 Gy that some of the highly irradiated seeds do in fact germinate. This type of germination is only due to stretch growth of the cells, for the ability of the cells to divide has been loss. Real growth will never commence, and the germ plant will die after about a week.

The effect of a given dose varies with the type of plant. The effect is least in yellow mustard and increases for flax, rape, wheat and barley in that order. A few yellow mustard and flax plants will survive the 800 and 1600 Gy doses, while these doses are lethal for barley. The sensitivity of various plant types to radiation is due in part to the size and the number of chromosomes. Plant types with large chromosomes and low chromosome number (e.g. barley) will usually be more sensitive than a plant type with small chromosomes and higher chromosome number (e.g. yellow mustard and flax).

When the radiation deposits its energy in plant tissue, strongly chemically active ions (free radicals) which react with neighbor molecules are formed, so that some chemical compounds are altered. This can cause alteration or termination of normal plant cell functions (somatic damage). Part of the action occurs in the DNA molecules of the plant cells causing mutations or chromosome breaks (genetic damage). This damage can also contribute to the breakdown of the normal processes in the cell.

Sensitivity variations

The sensitivity of the individual cell to radiation is dependent upon a number of factors such as for example their water content and temperature during and after exposure.
The storage time after exposure is also important, as the growth impediment increases with storage time. (This can be the explanation for differing experimental results over time.)

The radiation sensitivity exhibited by the various types of plants depends also upon the growth period and the environment during the growth of the plants. The effect of this factor can be studied by varying the growth period. It is a prerequisite that the environmental factors are held constant during the growth period.

Variations in the growth period

The heights of the plants are measured 3 to 6 times at 2 or 3 day intervals. The radiation dose which reduces the plant height to 50% of the height of the unexposed plants is found (termed LD-50). LD-50 can be displayed in a coordinate system as a function of the growth period. The results will usually show that LD-50 changes with time and that the changes will differ among plant types.
The plant seeds are generally much less sensitive to radiation than growing plants and much less sensitive than mammals. The lethal radiation dosage (LD-50) for plant seeds is usually in the range 200-2000 Gy and for growing plants 50-500 Gy. For mammals, including humans, the lethal dosage is around 5 Gy. It will not be possible to observe the mutations caused by radiation (induced mutations). The first mutations which occur go in the recessive direction (A → a) so that their effect is hidden by the non-mutated allelers effect (A). After self-pollination by a mutant heterozygot (Aa) the mutant gene will appear homozygous (aa) in the descendants through the segregation:

$$Aa \times Aa \rightarrow 1\ AA : 2\ Aa : 1\ aa.$$

Mutations induced due to irradiation of seeds can occur in the cells in the germbud as well as the germroot, germleaf, seedmaterial etc. Only mutations induced in the cells of the germbud will be transferred to the descendants, for these cells are reproduced and contribute to formation of the adust plant and its flowers and seeds.

The seeds have been produced by the Risø Research Center, DK-4000 Roskilde, Denmark.