EFFECTS OF THE LENGTH OF X-RAY WAVES ON SEEDS

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The effects of x-rays on seeds have been investigated by a number of observers. It is generally agreed that a heavy dose of x-rays is injurious to the plants and retards growth. Some observers have noticed, however, that a small dose is in general beneficial to plants. Shull and Mitchell[1] have found that in the case of seeds of wheat and corn irradiated with x-rays, the plants have shown for a certain dose a marked increase in size and foliage. On the other hand Johnson[2] found no such increase for tomatoes, sunflowers and for other plants. The object of this investigation was to study the effects of moderate x-ray doses on seeds.

The experiments conducted by Shull were repeated on the type of seeds used by him, namely, the golden yellow dent corn. The experimental set-up was similar to that employed by Shull. An x-ray tube with a 45° target operated at 5 milliamperes and 100,000 volts was used. The seeds were placed 30 centimeters from the target and the only variable used was the time of exposure. The x-rays were filtered through a 1 mm. of aluminum.

The seeds after exposure to x-rays were planted in large pots in a greenhouse; there were 12 seeds in each pot. The height of the plants was measured at regular intervals and the average height was plotted as a function of the dose. For a certain date the plants of the seeds exposed for three minutes were largest in size, in agreement with the results obtained by Shull.

However, it was found that this increase over the other plants did not prevail for very long. When the growth of the plants is plotted for a later date the curve shifts and the maximum height shifts to another dose. At a later stage of the growth the plants of the seeds exposed for four minutes were larger than those of the three minute exposure. The optimum dose determined in this way evidently holds only for a given stage of the growth of the plant and cannot, therefore, be used as guide when the yield at maturity is desired. Several series of experiments have been made, which indicate the validity of this conclusion. This will be discussed later.

The biological effects of the wave-length of x-rays on matter seems to be a subject of controversy. From the point of view of the physicist the effects of x-rays are entirely due to the absorption of the radiation by the material, and the consequent ionization of the atoms produced directly by the x-rays as well as by the ejected photoelectrons. On this view there should be no difference between the action of long x-ray waves and short waves so long as the energy absorbed is the same. This view seems to be

held by a number of observers. On the other hand, some observers report that x-rays of long wave-lengths have specific effects, that they are injurious to life even in comparatively small doses.[3]

TABLE I

GROWTH CHART. AVERAGE HEIGHT IN CENTIMETERS

SERIES	TIME OF EXPOSURE IN MINUTES		WEEKS AFTER PLANTING								
			3	4	5	6	7	8	9	10	11
A	$\lambda = 0.6A°$	1	11.0	21.0	29.4	33.2	41.0	43.3	48.6	59.0	*
		2	10.8	20.0	29.7	36.1	47.0	52.0	58.3	69.3	
		3	10.8	21.0	30.9	37.0	44.6	49.0	57.0	66.3	
		4	10.6	17.7	27.7	33.8	46.0	53.6	60.6	74.3	
		5	13.6	24.5	34.4	40.5	53.0	60.3	75.3	87.3	
B	$\lambda = 0.4$	0	15.5	25.0	34.0	37.6	40.5	47.6	48.3	49.0	61.6
		1/2	16.4	26.7	36.8	41.3	44.4	53.6	54.0	55.6	64.0
		1	12.7	21.4	32.1	39.2	43.4	56.6	58.3	64.6	69.6
		2	14.0	24.5	34.7	41.0	45.0	50.3	52.3	54.3	61.0
		3	12.7	20.0	29.6	35.5	40.0	50.6	52.3	56.6	66.3
		4	10.4	17.4	24.8	33.4	40.3	55.6	57.0	65.3	70.6
C	$\lambda = 0.3$	0	11.6	22.0	31.7	36.6	40.0	48.0	50.6	55.3	61.0
		1/2	10.4	20.3	28.3	34.4	38.4	48.6	51.3	56.6	66.3
		1	10.0	23.3	32.2	39.3	43.7	51.3	53.6	60.0	69.0
		2	14.1	27.6	37.0	42.5	47.6	53.6	55.6	60.6	65.6
		3	5.6	12.1	20.3	27.3	36.0	52.6	56.6	66.0	72.0
		4	5.4	10.6	14.2	22.4	33.8	50.0	52.3	61.0	65.3
		5	3.3	6.5	14.3	21.3	31.3	59.5	60.3	71.0	77.1
D	$\lambda = 0.2$	0	18.5	28.0	35.8	40.5	43.4	51.0	52.0	55.3	66.3
		1/2	16.1	26.6	33.7	39.3	43.0	51.3	52.6	56.3	66.0
		1	15.0	20.0	33.8	39.0	43.4	52.6	54.6	59.0	68.0
		2	14.8	23.4	32.2	38.9	41.9	52.0	53.6	57.3	63.3
		4	15.3	24.7	31.2	36.6	38.4	44.6	46.3	50.0	60.3
		6	4.2	8.1	15.8	24.8	35.3	57.0	59.6	65.3	70.0
E	$\lambda = 0.12$	0	11.1	21.8	30.9	35.8	44.6	47.0	54.3	66.0	*
		1	11.5	23.2	31.5	38.3	48.3	51.3	56.6	65.6	
		2	9.1	18.6	29.0	37.6	55.0	37.3	63.6	73.3	
		3	5.4	11.0	19.5	30.5	52.3	59.3	66.0	74.0	
		4	5.0	14.0	22.1	31.8	52.6	57.6	64.3	70.0	
		5	2.2	7.0	16.0	26.0	40.0	41.0	41.0	41.0	

* Plants too large to remain in pots.

In order to test the validity of either of these points of view exposure to x-rays of five different wave-lengths obtained by proper potential across the tube and proper filtering were made on seeds of corn. The effective

wave-length ranged from 0.6 to 0.12 angstrom unit. For each wave-length five or more exposures varying in time were made on different batches of seeds.

In order to have comparable results for all the series the distance of the seeds from the target was adjusted so that the seeds absorbed approximately the same quantity of x-ray energy for the same length of time of exposure. The seeds were planted in pots in a greenhouse. In all there were twenty-eight pots.

The growth of the plants was recorded every week and the results are tabulated below. An examination of the data discloses the following features:

(1) There seems to be no significant difference in the effects of radiation of the different wave-lengths used. The size of plants exposed to x-rays for an equivalent time of one minute, for example, at any given date is not much different for any given wave-length.

(2) Larger doses seem to exert inhibitive effects in most cases. (The five minute exposure of series one seems to be exceptional in this respect.) It is to be observed, however, that this inhibitive action is only temporary in character. The seeds in time attain the same height and in some cases a larger height inside of a few weeks. (The five minute exposure in series 5 should be disregarded. Something was obviously wrong with this particular set as the seeds have not shown any growth for several weeks.)

(3) It was mentioned previously that the optimum dose at one date may be different from the optimum dose at another date. For example, in series C seven weeks after planting the two minute dose seems to produce a greater height of plants than any other dose. However, a week later the five minute exposure seems to yield best results.

Another series of experiments with 21 pots was made very recently giving essentially the same results.

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[1] C. A. Shull and J. A. Mitchell, *Plant Physiol.*, **8**, 287 (1933).

[2] E. A. Johnson, *Am. Jour. Bot.*, **18**, 603 (1931).

[3] A comprehensive review of the literature on this subject is given in "Biological Effect of Radiation," Vol. 1, Ch. XIII, McGraw-Hill Book Co.