THE EFFECTS OF X-IRRADIATION ON THE GROWTH AND DEVELOPMENT OF JUTE PLANTS.

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INTRODUCTION.

The effects of X-rays on seeds and seedlings of various plants have been studied by a number of workers. A survey of the previous work on the subject shows that the results obtained vary considerably and no definite conclusions can be drawn from these regarding the effects of X-rays on seeds and seedlings in general. Johnson (1936) reviewed most of the literature on the subject up to date. It is, therefore, unnecessary to repeat it here, but a brief account of the main results obtained by the principal workers will be given. Mention is also made of some recent work.

It is generally agreed that the effects of X-rays on living material is more or less destructive. It is also known that medium and heavy doses check the growth of the plant parts; but the results obtained by using light doses are contradictory. Thus, Koernicke (1915), Pfeiffer and Simmermacher (1915), Geller (1924) and others reported that growth was retarded by stronger doses and stimulated by weaker ones. Ancel (1924) treated hundreds of seeds of the same species with weak doses of X-rays, but she did not observe any stimulating action. She concluded that the so-called accelerating effects of weak doses of X-rays did not exist. The stimulating influence of X-rays has also been demonstrated by Goodspeed and Oslon (1928), Goodspeed (1929), Jacobson (1923), Shull and Mitchell (1933) and others. A number of other workers have also reported that irradiation causes no stimulation but definite retardation in the growth of plants.

Several investigators have shown that radiation produces cytogenetic alterations in plants. Koernicke (1915), Komuro (1922, 1924), Goodspeed and Avery (1930), Goodspeed and Uber (1939) and others have shown striking chromosomal disruptions as a result of exposure to heavy doses of X-rays. They have also noted several other changes in the nucleus, such as, clumped, broken or fragmented chromosomes, irregular chromosome distribution, chromatin bridges between the daughter nuclei, nuclear aberrations, etc. The entire cell is affected by X-rays, but the nucleus seems to be particularly sensitive. Recently Sax (1938, 1940) has thoroughly investigated the production of chromosome aberrations in *Tradescantia* by the application of X-rays. Rick (1940) has also worked out the deletion of chromosomes in *Tradescantia*. Most workers [Rick (1940), Sax and Swanson (1941) and others] who studied the differential sensitivity of cells to X-rays agree that actively dividing cells are more sensitive to X-rays than those in the resting stage.

In comparison to the large amount of work done on nuclear alterations very little has been done to show the variation of form and changes in the internal structure of the plant. In the sunflower and tomato Johnson (1928, 1931) observed the elongation of cells of the radicle tip, great vacuolation of cells and absence of nuclei from many cells, increase of xylem at the expense of the pith, greater suberin development in the hypocotyl region, etc. As regards external features she noticed such changes as fasciation in stems, leaves and flowers, abnormalities in the shape and size of the leaves, development of lateral branches and other changes in floral and fruit development. In another set of experiments Johnson (1931) treated young seedlings of tomato at different intervals during growth and obtained such effects as leaf anomalies, development of many lateral branches thus producing bushy appearance, abnormalities of floral parts, delay in fruit development, greater development of the placenta and an almost total absence of seeds in the fruit. She

also observed radiophylaxis, that is, a lessening effect of higher dose when the plants were given preceding lighter doses.

Practically all the workers agree that soaked or germinated seeds are more sensitive to X-irradiation than resting ones. From the contradictory reports of the different workers it seems that different kinds of seeds react differently to different doses of X-rays. Further, there are plants which are less sensitive to radiation than others and a less sensitive plant requires a greater dose for either retardation or stimulation than a more sensitive one (Halberstaedter and Simons, 1922).

Material and Methods.

The present work was undertaken with a view to study the development and structure of jute plants (*Corchorus capsularis* (D 154) and *C. olitorius* (Chinsurah Green) raised from irradiated seeds.

Two sets of experiments were carried on, one with dry seeds and the other with seeds soaked in water. In the first, air-dried seeds were treated with different doses of X-rays. For experiments with wet seeds, the seeds were soaked in water for a period of 6 hours and then exposed to the action of X-rays. Fifty seeds were exposed in each case. The following tables show the different marks given to the treated seeds according to the doses applied :—

Dry Seed Treatment (D = D 154; C = Chinsurah Green).

Marks.	K.V.P.	Current.	Filter.	F.S.D.	Time.	Dose.
D, C	..	..	..	..	..	Untreated.
D_1 C_1	40	4·5 m.A.	..	9 cm.	1 hr.	3360 R (medium).
D_2 C_2	40	4·5 m.A.	..	9 cm.	1½ hrs.	5040 R (medium).
D_3 C_3	40	4·5 m.A.	..	9 cm.	2 hrs.	6720 R (medium).
D_4 C_4	220	5 m.A.	Thoreus 0·2 mm. Cu.	80 cm.	13·5 mins.	202·5 R (penetrating).
D_5 C_5	220	5 m.A.	Thoreus 0·2 mm. Cu.	80 cm.	27 mins.	405 R (penetrating).
D_6 C_6	220	5 m.A.	Thoreus 0·2 mm. Cu.	80 cm.	40·5 mins.	607·5 R (penetrating).
D_7 C_7	25	4·5 m.A.	..	20 cm.	2·5 hrs.	2100 R (soft).
D_8 C_8	25	4·5 m.A.	..	20 cm.	5 hrs.	4200 R (soft).

Wet Seed Treatment (D = D 154; C = Chinsurah Green).

Marks.	K.V.P.	Current.	Filter.	F.S.D.	Time.	Dose.
D′ C′	..	..	..	..	..	Untreated.
D'_1 C'_1	200	15 m.A.	0·5 Cu + 1 Al	30 cm.	6 mins.	518·4 R (penetrating).
D'_2 C'_2	200	„	„	„	24 mins.	2073·6 R (penetrating).

Germination of Seeds.

The study of the germination results of dry seeds shows that germination is definitely increased in *C. capsularis* seeds treated with soft rays; the results of such seeds treated with penetrating doses seem to be peculiar; as out of the three sets of treated seeds germination was enhanced in two cases; all the seeds treated with medium doses did not show any stimulation. No stimulation in germination was observed in any of the treated seeds of *C. olitorius*.

External Features of Plants raised from Dry and Wet Seeds.

Roots.—No abnormality in the development of roots or increase in root growth was noticed.

Stems.—A change in the general appearance of some plants raised from irradiated seeds was noticeable. Normal jute plants are straight and with very little development of lateral branches; several of the treated plants, however, developed

branches early and assumed a bushy appearance (see Tables I and II). Usually at the flowering stage stems of jute plants bifurcate at the tips and produce branches. In some plants of the wet seed treatment, however, bifurcation of the tips occurred at a very early stage when they were about only 1 foot in height. The bifurcation appeared between the 4th and 5th week from the date of sowing. At this period there was no bifurcation in plants raised from X-rayed dry seeds.

TABLE I.

Lateral branch development in *C. capsularis* (63 days after sowing).

	D	D_1	D_2	D_3	D_4	D_5	D_6	D_7	D_8	D′	D'_1	D'_2
Number of plants counted ..	10	10	10	10	10	10	10	10	10	10	10	10
Total number of branches ..	16	30	32	38	54	65	50	42	43	13	38	72
Average number of branches per plant	1·6	3	3·2	3·8	5·4	6·5	5	4·2	4·3	1·3	3·8	7·2

TABLE II.

Lateral branch development in *C. olitorius* (63 days after sowing).

	C	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C′	C'_1	C'_2
Number of plants counted ..	10	10	10	10	10	10	10	10	10	10	10	10
Total number of branches ..	18	27	34	32	65	71	64	31	32	20	39	68
Average number of branches per plant	1·8	2·7	3·4	3·2	6·5	7·1	6·4	3·1	3·2	2	3·9	6·8

Besides early bifurcation and lateral branch development a change in the phyllotaxy was observed only in a few plants. Two or three leaves were also found to spring from each node; this was due to the fact that a few of the internodes became so shortened in length that the leaves appeared to develop from the same node.

Leaves.—The cotyledons remained normal in the seedlings of both dry and wet seed treatments. Most of the mature plants showed no striking abnormality of the leaves; several plants from both treatments, however, developed leaves with light green or yellowish patches mingled with dark green areas, thus giving rise to a somewhat mosaic appearance. A few of the plants also showed curling of some of their leaves.

Flowers.—Any marked difference of floral stucture was not noticed. The number of days after which jute plants flower, depends on the date of sowing; thus plants sown earlier in the season take much longer time to flower, whereas those sown later come to flower in comparatively shorter time. The appearance of flowers in plants raised from irradiated dry seeds was simultaneous with that in the untreated plants and in them no variation in the structure of the flowers was observed. The plants raised from treated wet seeds, however, flowered comparatively later; and the flowers of those plants also did not show any variation. The following table shows the time for the first formation of buds in such plants and the number of flowers developed 80 days after sowing :—

TABLE III.

Development of flowers in plants of the wet seed treatment.

	D′	D'_1	D'_2	C′	C'_1	C'_2
Number of plants counted ..	10	10	10	10	10	10
Average number of days after sowing when first bud appeared ..	64	70	71	63	72	73
Total number of flowers after 80 days	200	183	174	210	175	172
Average number of flowers per plant after 80 days	20	18·3	17·4	21	17·5	17·2

Fruits.—Fruits were generally normal in plants of both treatments. In a few cases in plants of the wet seed treatment it was observed that the placental tissue developed considerably and the number of seeds in the fruit decreased.

General Growth and Development.

A periodic study of the increase in the height of the plants showed that growth was retarded in plants raised from irradiated seeds during the first few weeks, but later on they revived and developed quite healthily. Generally for a period of about three weeks there had been retardation in the growth of the seedlings; but afterwards the plants revived and later on attained the same height as attained by the normal plants. In a few cases some plants of *C. olitorius* raised from wet seeds treated with a penetrating dose became taller than the normal ones.

Another interesting feature of many plants raised from irradiated wet seeds is that the tips of the stems of some plants withered at a very early stage. The apical buds turned brown and appeared as if burnt. The destruction of the apical buds did not cause the death of the plants but resulted in the production of a number of lateral branches below the burnt tip.

Internal Characters of the Plants.

Roots and Leaves.—No characteristic difference in the internal structure of the roots and leaves was observed.

Stems.—The stems showed some peculiarity in anatomical features. The xylem or woody tissue developed to a greater extent in most of the plants raised from irradiated seeds. The pith was also comparatively reduced. The rows of fibre strands in the phloem wedges also slightly increased in number, but the number of the wedges was decreased.

Nature of the fibre cells.—Differentiation of fibres in all the cases started in the phloem region as soon as the internodes reached maturity. Fibres were counted from transverse sections taken from different portions of all the treated plants as well as from the control. Comparative counts showed no appreciable difference in number among the treated plants; the number of fibres in the different regions of the plants raised from X-rayed seeds nearly equal the number of fibres in the corresponding regions in the normal plants.

It is found that due to the effects of irradiation no characteristic change in the shape and size of the fibre cells took place. The fibre cells on the outer side of the stem (first-formed or protophloem fibres) were as usual longer and thicker than those of the inner regions (secondary phloem fibres) (Kundu, 1942).

Discussion and Conclusion.

From the above results it may be concluded that treatment of jute seeds, both dry and wet, by X-rays produces few characteristic changes in the plants. According to Koernicke (1915), Pfeiffer and Simmermacher (1915) and others the rate of germination is higher in seeds treated with mild doses of X-rays, but Ancel (1924) reported that the rate did not accelerate in air-dried seeds with varying doses of X-rays. In our experiments the rate of germination did not accelerate in the seeds of either species of jute except in the air-dried seeds of *C. capsularis* treated with soft heavy doses and light penetrating doses.

Johnson (1931, 1933), Horlacher and Killough (1931) and Goodspeed (1929) observed striking changes in the shape and size of the leaves and also various other leaf anomalies in different plants raised from irradiated seeds; no such abnormalities in the leaf structure were seen in this case. Horlacher and Killough (1931) observed that the shape and size of cotton seedlings from X-rayed seeds were very much affected. Such anomalies had not been observed in jute. The cotyledons of jute seedlings raised from dry or wet seeds did not show any change in size or structure; Johnson (1928) also observed the same in sunflower.

The production of lateral branches in jute plants from X-rayed seeds was much greater than that in normal plants. Several plants branched profusely and gave a bushy appearance. These results agree with those of Johnson for sunflower and tomato. The most vigorous branching was observed in plants of *C. capsularis* raised from wet seeds irradiated with a heavy penetrating dose. In *C. olitorius*,

however, the largest number of branches developed in plants grown from wet seeds treated with penetrating light doses.

In no case did I observe any fasciation of the stems as observed by Johnson in sunflower and tomato. None of the jute plants showed any dwarf habit as seen in tobacco plants by Goodspeed (1929).

Various abnormalities in the structure of the flowers was observed by Johnson, Goodspeed and others. In jute, however, no abnormality in the structure of the flowers was seen. Flowers in plants raised from irradiated dry seeds developed simultaneously with those in the normal plants. Retarded blossoming was observed in plants of the wet seed treatment. Late development of flowers in plants raised from X-rayed seeds was also recorded by Johnson (1936) in many species. In a note on their studies on the physiology of jute Sen Gupta and Sen (1944) observed that no difference on the rate of growth, height, internodes and onset of flowering could be seen between the controls and treated plants as the result of X-ray treatment.

The present observations are in agreement with those of Miege and Coupe (1914), Altmann, Rochlin and Gleichgewicht (1923) and Johnson (1926, 1928) in regard to the increase of the xylem tissue and the proportionate decrease in the extent of the pith in the stem.

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Summary.

1. By treating jute seeds, both dry and wet, by different doses of X-rays few characteristic changes in the plants are produced.
2. Plants raised from irradiated seeds appeared to lose their vitality during the early stages of their growth, but later on their development was quite normal.
3. There had been an early development of branches in some of the plants raised from X-rayed seeds; and some plants assumed a bushy appearance on account of the growth of many branches.
4. Some plants raised from irradiated wet seeds showed bifurcation of the tips at an early stage of growth.
5. The leaves, flowers and usually the fruits in all plants developed from X-rayed seeds did not show any abnormality. There had been some delay in flowering in plants from X-rayed wet seeds.
6. In the stems the amount of woody tissues (xylem) increased to some extent in nearly all plants developed from irradiated seeds.
7. The shape and size of the fibre cells were found to be unchanged.

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