

GROWTH MODIFICATIONS IN CITRUS SEEDLINGS GROWN FROM X-RAYED SEED

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(WITH SEVEN FIGURES)

A summary is made in the present paper of certain morphological variations observed in seedlings of the citrus fruits arising from seed exposed to x-rays before planting. The work has been undertaken in the course of a series of investigations on the biological effects of x-rays and cathode rays, and although as yet no cytological examination of the material has been made, it was considered worth while to assemble descriptions of certain morphological effects at the present time, in view of the paucity of x-ray work reported with the citrus fruits, especially at higher voltages and currents. Certain of the variants considered have already been described,¹ but have been included here in order to complete the series.

Seeds of lemon, lime, tangerine, grapefruit, and sweet and sour orange were obtained through the kindness of Dr. R. G. LARUE, Superintendent of Cultivation of the University of California Agricultural Experiment Station, and Dr. A. F. CAMP, Head of the Department of Horticulture of the University of Florida. They were dried previous to shipment. A portion of the seed was x-rayed in the condition in which it was received. The remainder, before treatment, was soaked in distilled water for 15 minutes, then left in a completely moisture-saturated atmosphere for 12 hours. The seeds were then dried on filter paper and exposed at once. Treated seeds were planted immediately in seed flats, a mixture of one-third peat moss and two-thirds sharp sand being used, the seeds being covered in most cases with pure sharp sand. The seeds were germinated in an electrically heated greenhouse, day temperatures being maintained constant at 75° F. and night temperatures at 55° F. during the early growth of the plants. At a later time a large number of apparently normal seedlings were transferred to the open nursery, being planted in a sandy loam soil. Most of the more conspicuous variants were maintained in the greenhouse for a full year, however, being transferred to benches containing a mixture of sand, clay, and manure at the age of a few months. After this change they were not disturbed until the close of the experiment.

A Coolidge water-cooled tungsten-target tube of the thick-walled type was used as the source of x-rays, operated at 200 k.v.p. and 30 ma. from a

¹ Science, Aug. 5, 1932.

Science, Feb. 15, 1933.

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high-tension transformer equipped with Snook mechanical rectifier. The seeds were exposed on a lead-covered table at a focal distance of 50 cm. Under these conditions the incident energy input, as measured with a graphite-covered collodion wall, radium-compensated Failla ionization chamber, was 165 roentgens per minute. The shortest wave length theoretically obtainable at this voltage is 0.062 Å. as calculated from the quan-

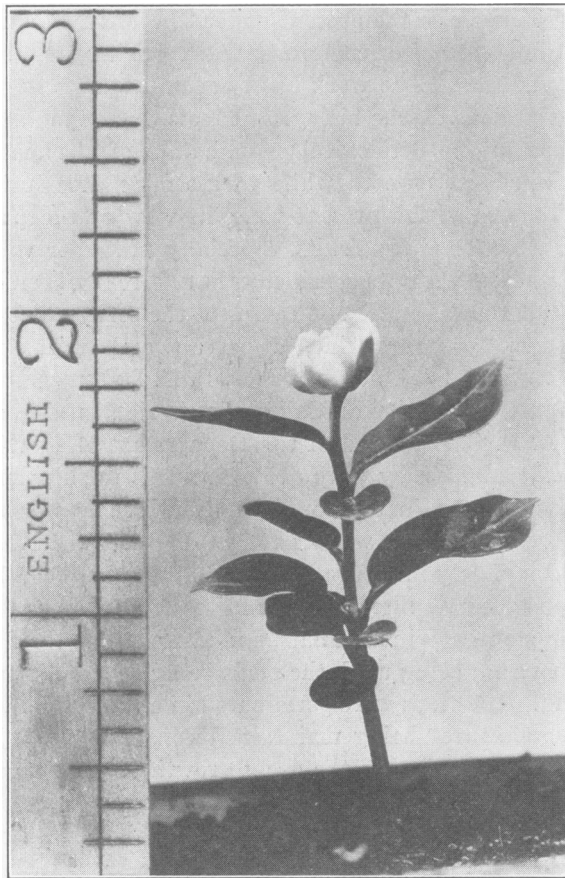


FIG. 1. Grapefruit seedling flowering prematurely after x-ray treatment of seed from which it came. Dosage 300 r.

tum relation $Ve = hv_{\max}$. No metal filter was used, but the glass of the wall interposed a filtering action equivalent to about 0.10 mm. of copper. At 0.70 Å. the intensity of the emergent radiation was only about 0.3 per cent. of that impinging on the inner wall, as calculated from COMPTON'S 1926 value for the mass absorption coefficient of copper,² and this may be con-

² COMPTON, A. H. X-rays and electrons.

sidered the cutoff point. Substantially all of the radiation incident was included between these points, the greatest intensity lying within the $K_a - K_b$ doublet region for tungsten, between 0.21 and 0.18Å.

Several very curious effects were observed among the seedlings, which may be summarized here.

Premature flowering

Premature flowering is not infrequently observed in citrus seed beds, particularly in cases in which the acidity of the soil has not been properly

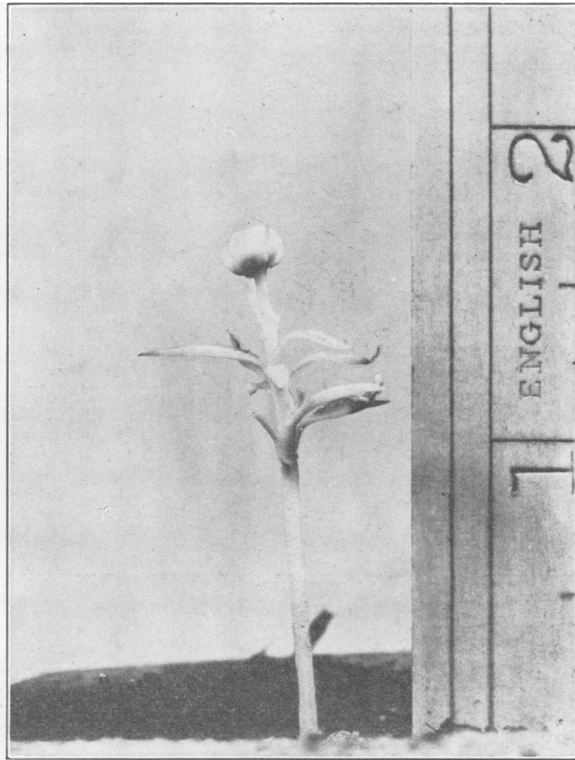


FIG. 2. Premature flowering of a chlorophyll deficient grapefruit seedling. Dosage 1300 r. in seed stage.

regulated. In the present case, however, the habit was pushed to an extreme which proved very interesting, especially in view of the fact that the hydrogen ion concentration of the seed beds was maintained within limits which, in the opinion of the citrus growers, should discourage early flowering.

Among one group of grapefruit seedlings arising from seeds which had been given x-ray dosages of from 300 to 1300 roentgens in both the wet and

dry states under the conditions described, two came into flower within six weeks of the time of sprouting. The flowers matured rather slowly, but, although diminutive, they proved to be normal in form. The plants, as shown, still carried the first pair of leaves intact, as is usual with citrus seedlings of this age. The plant shown in figure 1 was normal in leaf and flower coloration, and the leaves were nearly normal in form although somewhat elongate and diminutive. The other seedling (fig. 2) was extremely deficient in chlorophyll and the flower was imperfectly pigmented, being of a yellowish white color similar to the leaves. The stamens, however, were golden. The green plant received a dosage of 300 roentgens and the white one a dosage of 1300 under the same conditions.

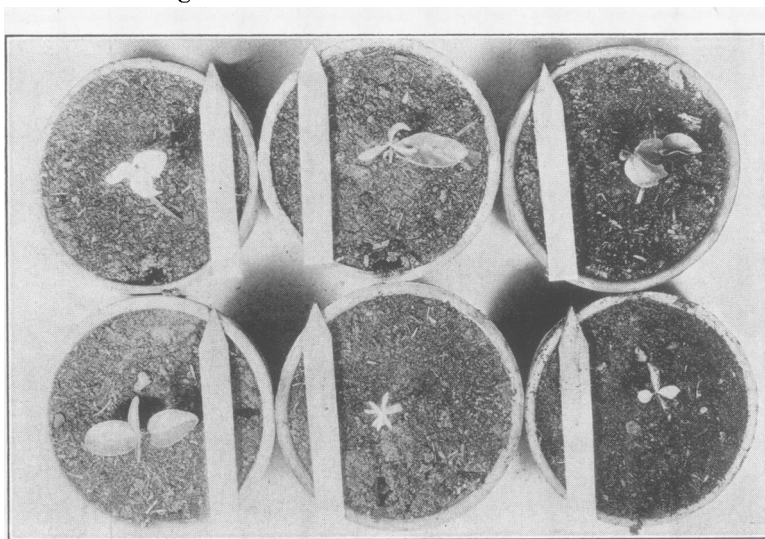


FIG. 3. Albinism of citrus seedlings following x-ray treatment in the seed stage.

The plant deficient in chlorophyll died very shortly, as was to be expected. The normally pigmented seedling, although deficient in roots, survived and grew slowly, and, when one year of age, again showed a flower bud on new growth, although it did not come to maturity.

At the age of nine months, 10 per cent. of this entire planting came into blossom almost simultaneously, the flowers in this case being of normal petal number and almost of normal size. Some of the flowering seedlings were of normal stature for their age, while others were distinctly dwarfed.

Albinism

Albinism, like premature flowering, is a character not infrequently apparent among citrus seedlings, especially in highly hybridized strains. In

the present case, however, an abnormally high percentage of seedlings showed this deficiency. It ranged from a condition best described as virescent, in which by no means all green pigment was lacking, through partial deficiencies in which a deep green was mottled irregularly throughout the leaf on a white background (fig. 3), to the complete whiteness characterizing one of the flowering types mentioned in the last section, and very many plants otherwise normal in appearance. Although albino plants were not absent from control plantings (as they very rarely are), the percentage of deficiencies in treated groups was manyfold higher.

Fasciation

Numerous cases of terminal and lateral bud fasciation were observed, the most pronounced of which is illustrated in figure 4, right. This speci-

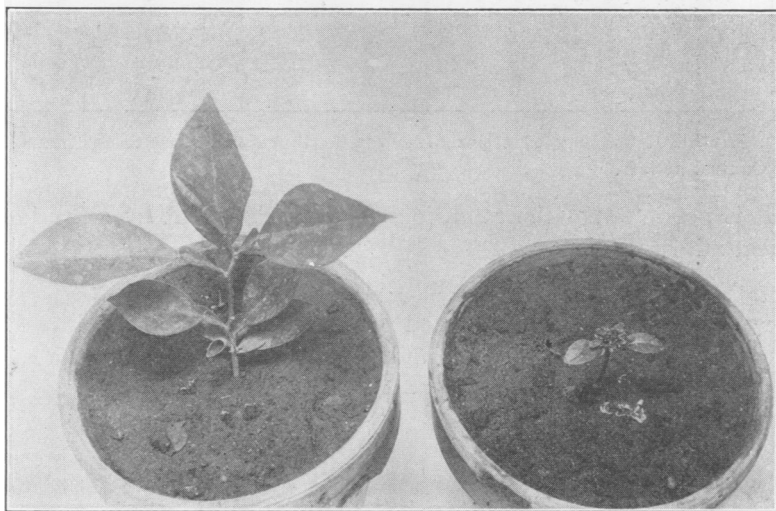


FIG. 4. Bud fasciation in *Citrus aurantium* following x-ray treatment of seeds. Control at left.

men of *Citrus aurantium*, when photographed, was but little over an inch in height. Control specimens, as is usual with this species, grew vigorously, and had attained a height of 10 inches when the photograph was taken. Clearly the primordia only of the later true leaves were affected, since the plant appeared normal in the first few weeks of life. Curiously the later leaves, although diminutive, were of nearly normal form.

Twisting

Two young seedlings from the time of sprouting showed a decided tendency to spiral in a counter-clockwise direction. Both plants twisted so markedly as to bend the stem from the vertical and to crush the leaves

against the stem (fig. 5, extreme right). After six months the habit was abandoned and later growth was normal. Both plants showed some evidence of tissue inversion and other characteristic x-ray injury during early

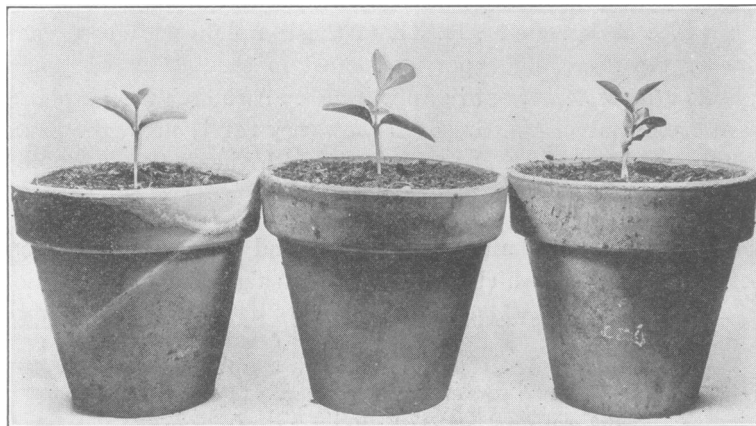


FIG. 5. Spiral twisting of stems of citrus seedlings following x-ray treatment of seeds. Control at left.

life. It is possible that the condition was brought about by x-ray induced abnormal mitoses.

Duplication

Very many instances were noted in which the midribs of leaves were split near the base, both halves being nearly equally robust. In a number

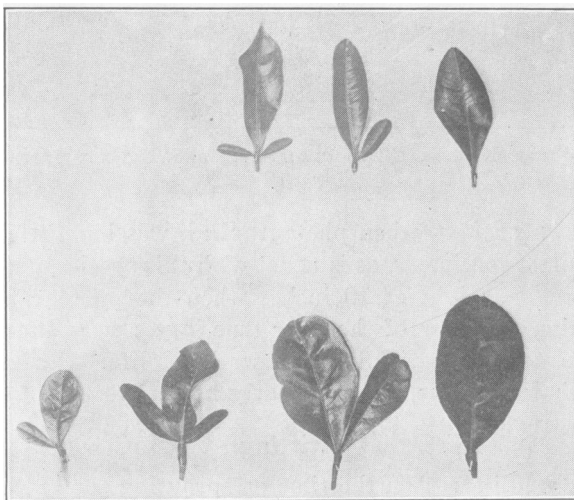


FIG. 6. Leaf modifications in citrus seedlings following x-ray treatment in the seed stage. See also fig. 5, center.

of cases, especially with the grapefruit, the entire leaflet was duplicated, the resulting two terminals usually being of nearly the same dimensions (fig. 5, center, and fig. 7). In lemon stock similar developments gave rise to partially bifoliate, bifoliate, partially trifoliate, and truly trifoliate leaves, often coexisting on the same plant (fig. 6).

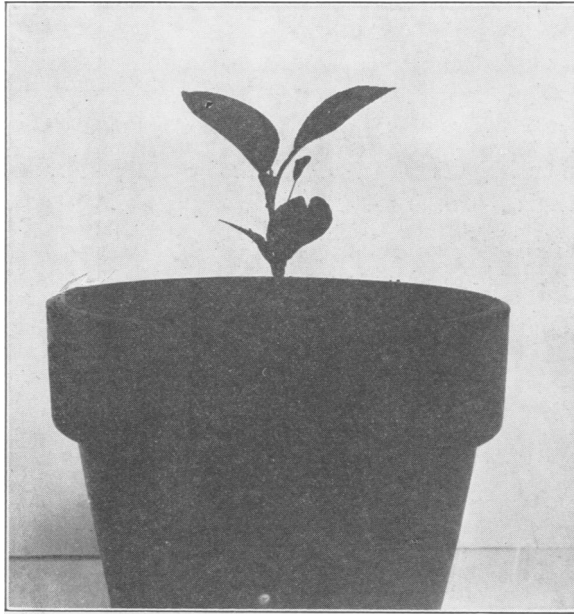


FIG. 7. Grapefruit seedling with modified leaf, and accessory cup-like leaf. X-ray treatment given in seed stage.

Peloric leaf formation

An interesting development of a cup-shaped type of peloric leaf occurred in two grapefruit seedlings from x-rayed seeds, in each case the leaves proceeding laterally from the stem at a point some distance below the terminal bud. The formation was new in the experience of the writers and in that of a citrus horticulturist who examined it. The peloric leaves persisted for more than a year, the plants bearing them being otherwise normal.

Work is being continued in the field, and through the kindness of Mr. W. J. PLATTEN, of Sebastian, Florida, grafts of several of these variants have been made on to rough lemon stock, with a view to checking any possible modifications in fruit.

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