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THE EFFECT OF CHRONIC GAMMA IRRADIATION ON
APICAL DOMINANCE OF TREES*

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Abstract--Cherry and apple trees subjected to low doses of gamma irradiation (average of 16 and 34 r/day) for 10 years produced atypical branch development and reversal of dominance which could be attributed to the decrease or inactivation of auxin resulting from the irradiation.

It has long been known that the concentration and distribution of auxin controls the development of buds and determines the growth habit of plants. The ancient techniques used to control growth and fruiting of fruit trees by girdling the stem, training the branches in a horizontal position, or by the use of a dwarfing root stock were, in reality, based upon the control of auxin and food movement. The effects of such horticultural techniques were attributed by Knight (4) to "the stagnation of the sap."

The exposure of plants to chronic ionizing radiation also results in atypical growth patterns. Gunckel (2) has shown that apical dominance may be lost in irradiated plants, often accompanied by fasciation and other abnormal growth patterns. The effect of X rays on auxin of plants was first observed by Skoog (6). He found that X-ray doses of less than 100 r resulted in a reduction of the auxin level. The relation between irradiation and auxin action has been well summarized by Gordon (1). He found that the irradiation of terminal buds of cocklebur with 200 r of X rays led to the growth of the lower axillary buds which normally remain dormant. The same effect is produced by decapitating the terminal bud. The effect of both techniques is attributed to the reduction in the auxin level which releases the lower buds from excessive auxin and permits their growth. The same effect is produced by the common

horticultural technique of cutting a notch in the stem above a dormant bud to stimulate its growth. The bending of a branch in a horizontal position, which promotes bud growth on the upper side of the branch and inhibits bud growth on the lower side, could also be attributed to differential auxin distribution.

The disturbance of apical dominance and the promotion of abnormal growth response has been observed in several herbaceous plants, e.g. Tradescantia (3), and in certain trees grown in the gamma field at Brookhaven. These trees included the "Hally Jolivette" ornamental cherry which is propagated by cuttings, and several species of apomictic apples, which were propagated from seed.

The trees were planted in the gamma field in the spring of 1953 at various distances from the gamma source. Those which survived were grown at 40, 56, and 77 meters from the gamma source. The strength of the Co⁶⁰ source varied from year to year ranging from about 1000 curies in 1958 to about 3700 curies in 1960. The exposure was for about 8 months during the growing season of each year from 1953 to 1959 but continuous from 1960 to the present. At 40 meters the total accumulated exposure was 83,460 r; at 56 meters, 40,320 r; and at 77 meters, 19,387 r. Over the ten year period the average daily exposure at 40 meters was 33.8 r; at 56 meters, 16.3 r; and at 77 meters, 7.8 r. In 1962 the average daily exposure was 43.6 r at 40 meters, 20.8 r at 56 meters, and 9.9 r at 77 meters. A more complete description of dosimetry and exposure periods is given by Sparrow, Schairer and Woodwell (7).

An examination in July 1962 showed a number of abnormal growth

patterns in the trees planted at 40 and 56 meters from the cobalt source. The most conspicuous aberration was the excessive axillary branching of the cherry trees which had received an average exposure of about 34 r per day (Fig. 1). The large clusters of lateral branches appeared to have originated from a great increase of meristematic tissue. They showed a high degree of apical dominance and were more upright in growth pattern than most of the normal single lateral branches.

When such a cluster of branches develops near the end of a small lateral branch the weight of the mass of clustered branches may rotate the slender stem so that the cluster of branches becomes pendant (Fig. 2). This reaction was checked by removing the branch well back from the pendant cluster of branches and splitting the stem, placing the end of one half in water, the other in an eosin solution until the wood was stained. When the bark was removed it was evident from the stained wood that the lateral horizontal branch had been rotated at an angle of 180° due to the excessive weight of the terminal cluster of branches. Apical dominance or geotropic reaction of these clustered branches soon led to an upright growth.

Apical dominance is weak in the Hally Jolivette cherry tree and the normal growth pattern is a small spreading tree with many lateral branches. Lateral branches from the main branches, even when these grow out at a nearly horizontal position, are about equally distributed around the main branch and those on the lower side make almost as much growth as those on the upper side (Fig. 3). When these trees are given a chronic exposure of about 16 r per day there is often a greater growth of the lower

lateral branches at the expense of the upper lateral shoots (Fig. 4).

Trees exposed to 34 r per day show an excess of lateral branches from the lower side of the horizontal branch. In Prunus tomentosa a few branches developing from the upper side of the horizontal branch often die (Fig. 5).

Similar cases of reversed polarity were found in the apple trees. Malus sikkimensis normally has a spreading growth habit, but a tree exposed to 34 r per day had pendant lateral branches which almost touched the ground before they began to grow more upright. The most striking case of reversed polarity was found in a Malus sikkimensis tree which had been exposed to 34 r per day (Fig. 6). The upright lateral branch had died at the tip and the branches that developed from an axillary bud grew downward with an apparent loss of negative geotropism.

The loss of dominance and reversal of geotropic response in the cherry trees could be attributed to the inactivation or loss of auxin so that the upper buds and branches were deprived of adequate auxin for normal growth. The limited auxin which moved to the lower side of the horizontal branch could be adequate for bud development and the resulting branches would tend to trap the limited available auxin by the effect of gravity. The apparent reversal of dominance or geotropic response in the apple branch could be attributed to a similar mechanism.

The mechanism which produces the large clusters of branches in the cherry trees is more difficult to explain. It is known however that ionizing radiation can be used to "girdle" a branch as effectively as removing a ring of bark (5). It is possible that even the relatively low dose of chronic irradiation could kill or retard enough of the cambium

cells so that replacement of phloem cells would be checked. This would reduce phloem transport and tend to prevent the basipetal movement of auxin and nutrients and thus perhaps accumulate locally to stimulate the enlarged shoot tip in the production of numerous branches.

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Fig. 1. A cluster of branches with increased apical dominance induced in the Hally Jolivette cherry tree by chronic gamma radiation of 34 r/day.

FIGURE 1

Fig. 2. Another cluster of branches at the end of the same branch shown in Fig. 1. Here the weight of the new growth has twisted the stem so that the cluster of branches hangs down, but apical dominance or geotropic reaction has led to the upward growth of the branches.

FIGURE 2

Fig. 3. A branch of the Hally Jolivette cherry growing in a horizontal position with lateral branches more or less evenly distributed around the axis of the main stem. This tree is typical of the control even though it received 8 r/day of gamma irradiation.

Fig. 4. A lateral horizontal branch of a Hally Jolivette cherry tree which had received 16 r/day of gamma irradiation. Most of the lateral branches have developed from buds on the lower side of the horizontal branch.

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Fig. 5. A branch of a cherry tree (Prunus tomentosa) given 34 r/day of gamma irradiation. Most of the lateral branches are on the lower side of the main branch and the branches ^{which} developed from buds on the upper side of the main branch have died at an early age.

Fig. 6. Reversed dominance in a branch of an apple tree subjected to 34 r/day of gamma irradiation.

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