men as being 93.5% of maximal or perfect conformity to the traffic regulations.

Reference

1. PETERS, C. and VAN VOORHIS, W. R. *Statistical procedures and their mathematical bases.* New York: McGraw-Hill, 1940. Pp. 82–84.

Histological Effects of Treatments with Growth-regulating Substances of the 2,4-D Group[1]

Arthur J. Eames

Department of Botany, New York State College of Agriculture, Cornell University, Ithaca

Recent anatomical studies of the bean plant (*2*) and nut grass (*1*) treated with growth-regulating substances of the 2,4-D group (2,4-dichlorophenoxyacetate) have shown that the internal modifications in the monocot are closely similar to those occurring in the dicotyledonous bean plant; and that a monocot, which from superficial study might be reported insensitive or slightly sensitive because of little or no external evidence of effect of the treatment, may be seriously affected in internal structure. Because of difference in method of growth in dicots and monocots the histological modifications naturally vary somewhat in the two plants in type and in position in the plant body, and the external form of the affected organs is modified in different ways. In monocots, external structural effects are commonly less evident than in dicots and may not be at all apparent if the plant dies soon after treatment. Detailed descriptions and photomicrographs of the anatomical modifications of the two plants under treatment are in the papers listed in the references.

In both plants, the modifications occur in immature tissues, as has long been recognized, or in tissues that, though mature, become readily meristematic, especially the pericycle and endodermis. Under both types of growth, primary phloem is distorted or destroyed. In the nut grass, the phloem of the vascular bundles in the growing leaf bases does not form or is destroyed as replacement tissue forms. The xylem is also distorted and its cells filled with gummy substances. The mature vascular bundles in the corm are uninjured. In the bean leaf also, the phloem is distorted or destroyed, and in the young bean stem the primary phloem is destroyed and no secondary phloem forms.

In addition to vascular distortion and reduction, two general types of modification occur: (1) That in which the course of cell and tissue development is so changed that the normal cells and tissues of the region are supplanted by a special type of fleshy parenchyma—with cells proportionately large, more or less irregular in form, strongly vacuolate, without chloroplasts, and with few or no intercellular spaces (Fig. 1B, D). This tissue is suitably called replacement tissue. (2) That in which

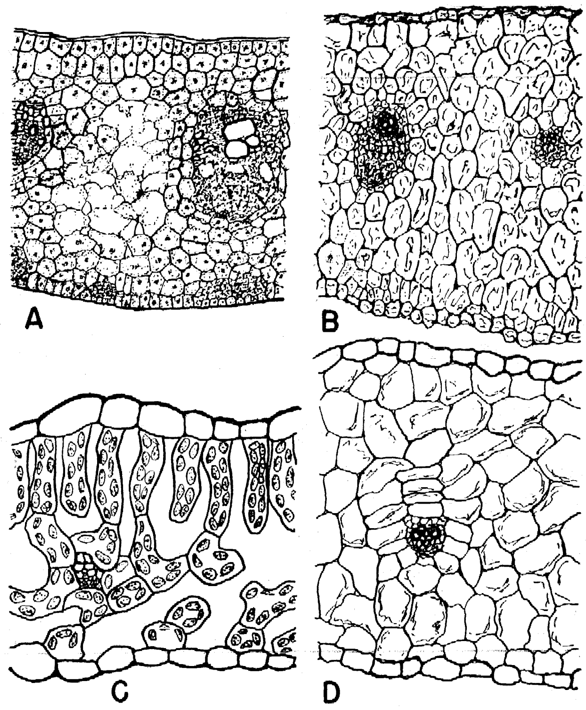

FIG. 1. Transverse sections of portions of normal and treated leaves of nut grass and bean plant. The treated leaves of both plants show increased thickness, replacement tissue, and abortive vascular bundles. A,B, nut grass: A, normal leaf nearing maturity, showing beginnings of differentiation of epidermis, mesophyll, vascular bundles, fiber strands, and aerenchyma; cells with much cytoplasm and conspicuous nuclei. B, treated leaf of about the same stage of maturity as A, lacking normal differentiation of tissues, showing replacement tissue with cells strongly vacuolate and cytoplasm scanty; the vascular bundles reduced and distorted. C, D, bean plant: C, normal mature leaf showing differentiation into epidermis, mesophyll, and small vascular bundle; mesophyll with abundant chloroplasts. D, mature treated leaf showing replacement tissue with cells strongly vacuolate, without chloroplasts: cytoplasm scanty; vascular bundle distorted.

the response is one of rapid and continuing proliferation of a layer or layers of cells somewhat similar to that of cambial activity (Fig. 2B, D), producing uniform, thin-walled parenchyma cells, some of which become richly cytoplasmic, closely resembling promeristem cells, and give rise to root initials. Proliferation from both vascular and nonvascular tissues is frequent in the young bean plant, with the new tissues arising chiefly from vascular derivatives. In the monocot stem, where there is no cambium, only pericyclic (and to a small extent endodermal) tissue takes part in the formation of new tissue. Proliferation in the stele may extend outward along the leaf traces.

[1] This paper is based upon work done for the Biological Department, Chemical Corps, Camp Detrick, Frederick, Maryland, under Contract No. W-18-035-CM-168 with Cornell University.

The first type of response (replacement tissue formation) takes place in the leaves and morphologically similar organs; here increase in thickness is minor. In the dicot, conspicuous distortion of external form is soon evident—extreme narrowing of the leaf blade caused by persistence of apical initials and inhibition of development of interveinal tissue (Fig. 3B) with some increase in thickness of blade. In the narrow-leaved monocot, external distortion is inconspicuous because there is little interveinal expansion in normal ontogeny, and with development from a basal intercalary meristem only a basal transverse segment of the leaf is affected (Fig. 3A).

The second type (proliferation tissue formation) occurs in stems (also observed in roots of the bean plant and other dicots and some monocots) and commonly results in extreme swelling of the organ with compression and rupture of the outer tissues, which do not take part in the proliferation. The cortex apparently is little or not at all affected.

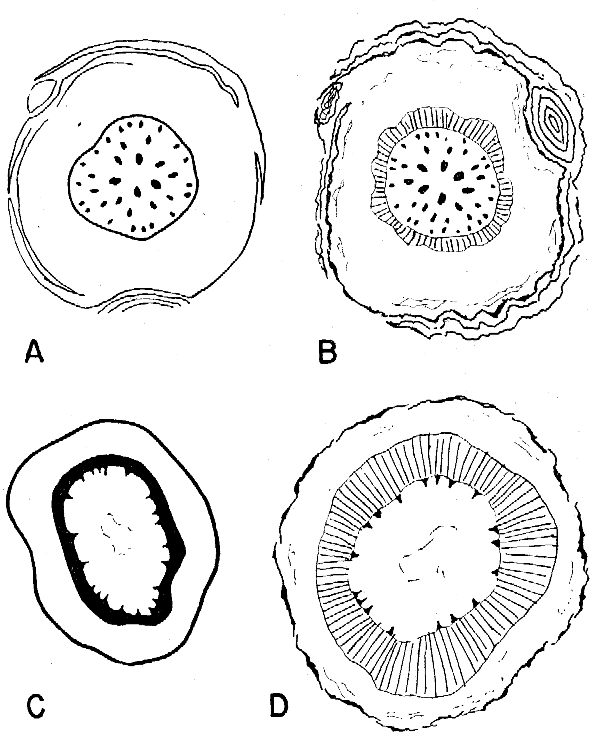

FIG. 2. Cross sectional diagrams of fairly mature corms of nut grass and young stems of the bean plant. A, B, nut grass: A, normal corm showing vascular bundles (black) in the central cylinder surrounded by the pericycle and endodermis (indicated by circle) and cortex with leaf bases and young rhizome tip; B, treated corm showing vascular bundles in the central cylinder as in the normal corm, proliferation of pericycle and endodermis (indicated by the lined area), the cortex somewhat crushed and torn, the epidermis ruptured, and the surrounding leaf bases shrunken. C, D, bean plant: C, normal stem showing vascular cylinder in black with points of protoxylem extending into the pith; D, treated stem showing pith and protoxylem as in the normal stem, proliferating tissue (indicated by the lined area) produced chiefly by the cambium and its derivatives in place of normal secondary vascular tissue, the cortex somewhat crushed and torn, and the epidermis ruptured.

Growth of replacement tissue to maturity is complete in a short time, about the same as in normal develop-

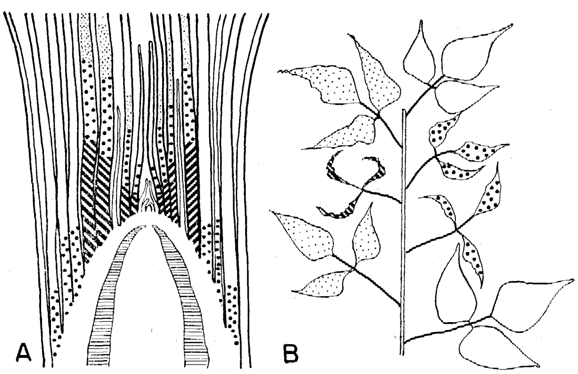

FIG. 3. Extent and distribution of injury in leaves of treated monocot and dicot. Hatching indicates regions of worst injury; large dots, regions of less severe injury; stippling, regions of least injury; and white areas, normal parts. A, diagram of median longtitudinal section of tip of corm and base of leaf fascicle of nut grass showing youngest and oldest leaves unaffected and between these the affected ones (immature at time of treatment). The leaf injury is externally inconspicuous because it occurs only in the basal portion of the leaf. In the worst-affected leaves, all three types of injury occur in one leaf. (Horizontally lined area in the corm indicates the proliferated tissue.) B, trifoliolate leaves of bean plant showing youngest and oldest unaffected, and varying degrees of injury in leaves between the unaffected ones. The injury in the bean plant is conspicuous because the whole leaf is distorted and an entire leaf usually shows one type of injury. (A, after Eames, modified; B, after Watson, modified).

ment; growth of proliferating tissue may continue for a long time. The same stimulus, however, produces both types of response, and is immediate and brief; there is no later stimulus without further treatment. The stimulus of 2,4-D treatments has been reported to be long-continuing in many plants, but these studies indicate that the reports are based on false interpretation of the evidence. Although the stimulus is immediate and brief, dormancy of some plants after treatment may delay the development of the affected immature tissues or organs (especially buds in woody plants and embryos in seeds) and external evidence of the injury is thus concealed until growth is renewed. Evidence of injury appearing in the spring following treatment is frequent in many plants.

From the anatomical study of this monocot and dicot it is clear that, although injury in the bean plant is far more conspicuous externally than in the nut grass (Fig. 3) because of the difference in method of growth, the modifications in both monocot and dicot are fundamentally the same (Fig. 1B, D; Fig. 2B, D).

References

1. EAMES, A. J. *Amer. J. Bot.*, in press.
2. WATSON, D. P. *Amer. J. Bot.*, 1948, **35**, 543.