INFLUENCE OF IRRADIATION ON THE DISTRIBUTION OF GROWTH IN DARK-GROWN AVENA SEEDLINGS

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SUMMARY

The influence of red and blue light on the distribution of growth in excised dark-grown seedlings of *Avena sativa* was studied. The changes in growth distribution seem to be in agreement with the hypothesis that light causes a decrease in transport of auxins from the tip downward, resulting in a higher concentration of auxins in the apical, and a lower concentration in the basal parts of the seedlings.

1. INTRODUCTION

Among the reactions of *Avena* seedlings to irradiation with light of different wavelengths, the correlation of the different growth reactions of different parts of the seedlings has not yet been sufficiently investigated. Data have been published on changes in growth and other reactions correlated with growth in different parts of *Avena* seedlings. Some describe the influence of light on growth and related phenomena, some the influence of other environmental factors. CURRY c.s. (1956) observed a change in the distribution of growth as a result from irradiation with red light in *Avena* seedlings (which had been grown during part of the cultivation period in red light causing a reduced mesocotyl length). HUISINGA (1964) observed changes in the magnitude of geotropic curvatures in different parts of totally dark-grown seedlings after irradiation with red, far-red and blue light. He tried to correlate some of the data in his hypothesis that differences in environment will cause differences in the transport of auxins from the tip downward. These result in differences in the distribution of auxin concentration in the seedling. The experimental results of Huisinga needed amplification. The restriction of the geotropic curvatures toward the tip of the seedlings should experimentally be correlated with the distribution of growth in the seedlings.

This paper describes a method that enabled the author to apply a series of equally spaced marks to *Avena* seedlings in total darkness. Data on the changes in the distribution of growth caused by irradiation are presented. In some experiments the distribution of growth and the distribution of the curvatures of the same seedlings were recorded simultaneously.

2. METHODS

Seedlings of *Avena sativa* "Victory oats" were grown in total darkness on moist filter paper as described in BLAAUW & BLAAUW-JANSEN (1964). All subsequent manipulations were performed in total darkness. After about 4 days the seedlings, having attained a length of about 5 cm, were cut from seed and roots. The length used was 3–3.5 cm. The plants were placed with their cut ends in receptacles filled with tapwater as described in HUISINGA (1964). Black marks, evenly spaced, were placed on the seedlings in the way described below. Irradiations were given and the plants were placed in darkness for 20 hours, either horizontal or vertical. At the end of this period a photograph was made on fine-grain film. To mark the seedlings in darkness a simple apparatus was constructed (*fig. 1*). It consisted of two parts. On one part (A) thin fishline was strung. The even spacing between the threads was obtained by winding the fishline in the grooves of two bolts with fine thread. The spacing between the threads was 0.35 mm. The other part (B) had, as principal feature, a pad of plastic foam. The marker substance (a mixture of very fine coal powder and paraffin oil) was applied in a thin film on a very slightly curved plate of perspex. The strings of part A were pressed in this thin film of marker substance. To mark the plants the plate with the plants placed in the holes (C) was slipped toward the part A until the seedlings touched the blackened strings. Part B was pushed in the direction of the plants and the pad of plastic foam was pressed against the seedlings. To measure the distances between the marks in the photograph we used a microscope with an objective lens of $\times 4$ and an ocular-micrometer. The distances between the marks were determined by measuring the distances from the tip of the seedling to each mark, and subtracting the resulting distances of two adjacent marks from each other. In this way accumulation of errors was avoided: the sum of distances between the marks was the same as the distance measured from the tip to the most basal mark. A consequence is that if one distance from tip to mark is erroneously estimated too large, the resulting distance from mark to mark above this mark will be found too large, the one below it will be too small for the same amount. The source of light used was either a red fluorescent tube

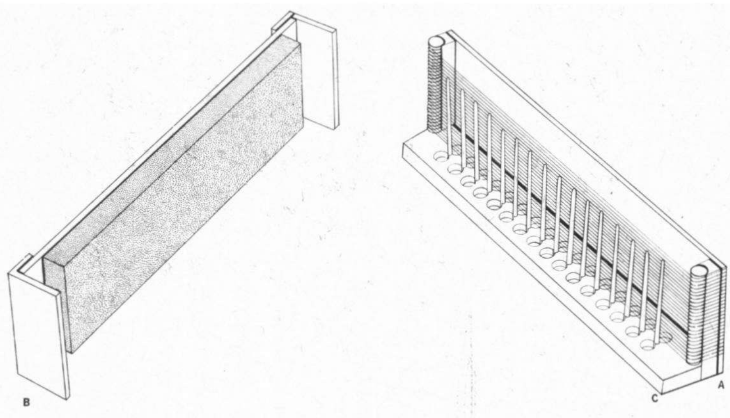

Fig. 1. Tool for marking seedlings. A: rack with strings; B: rack with pad of plastic foam; C: plate with excised seedlings.

combined with a red selenium glass (see BLAAUW & BLAAUW-JANSEN 1964) or an incandescent lamp with an appropriate system of lenses and a Schott double band interference filter. Energies were measured with a thermopile.

3. RESULTS

The growth pattern of plants that were either kept in total darkness throughout or had received an irradiation are shown in *figs. 2, 3* and *4*. In plotting the graphs to show the distribution of growth of the seedling, we did not have the exact distances between the marks at the onset of the experiment, because light was undesirable. We determined the accuracy of the distances between marks placed on seedlings immediately after placing them on a number of plants. The departure from 0.35 mm did not exceed 0.06 mm. The measurements of the distances after 20 hours were made with an accuracy not greater than 0.06 mm. The errors made in placing the marks on the seedlings are included in the final measure-

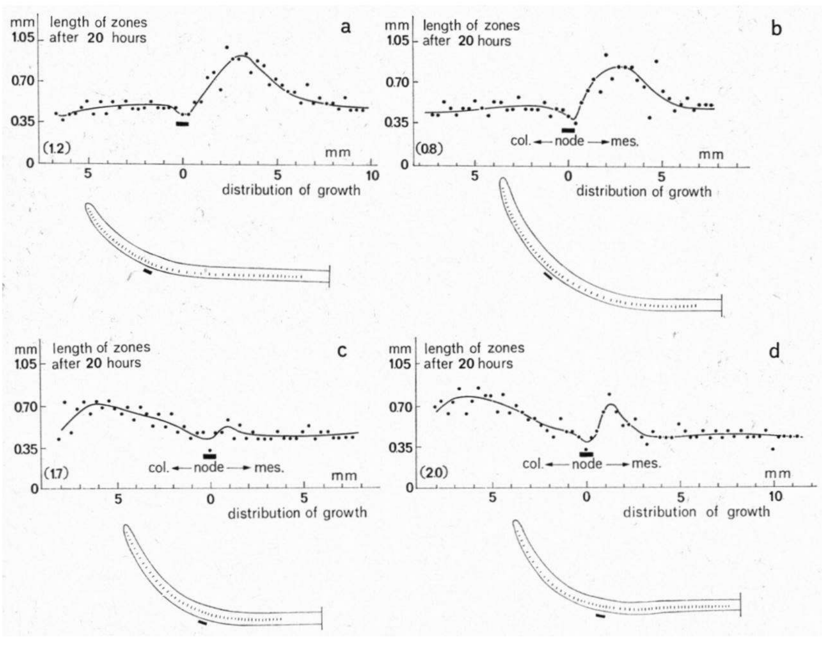

Fig. 2. Growth distribution and geotropic curvature of the same plants after 20 hours. On the abscissa millimeters are plotted. The distances measured along this axis are used as an approximation of the exact distances at the beginning of the experiment because these could not be recorded. The distance from the tip of the coleoptile to the first mark at the onset of the experiment is not known, not even approximately. This distance after 20 hours is given in brackets.

An accurate drawing from a photograph of the same plant as that from which the growth distribution is plotted, is shown beneath each graph.

a and b: dark; c and d: 40000 erg/cm² of red light (660 nm).

ments. The distances from the tips of the seedlings to the first mark could in no way be determined in darkness. An approximation is not possible, because, owing to curvatures in the plants, not all threads of the apparatus touched the plants at the tips. The distance between tip and first mark is given in each graph in brackets. It is clear that an irradiation with red or blue light will cause a decrease of growth of the mesocotyl. The growth of the coleoptile clearly increased. Irradiation strikingly restrics the part of the mesocotyl that is growing. Growth in the mesocotyl indicates strongly that the most vigorous growth takes place in the part that is located near the node. This is in agreement with the observation of MER & CAUSTON (1963) that just below the node a relatively intense cell division takes place, so that there cells have been formed that are, at the time of the experiment, in the best condition to show a vigorous elongation. In the coleoptile, which does not possess such a meristematic zone, the growth takes place more evenly distributed over the whole length as can be seen in the irradiated plants.

The combined data on growth distribution and geotropic curvature (*fig. 2*) show that a correlation does exist between growth and curvature. This is especially the case in the mesocotyl where no curvatures are found in the part that does not grow. This was as expected, because the mesocotyl appears to lack the ability to effect a lateral asymmetry of growth substance distribution (HUISINGA 1964). In *fig. 3* the growth patterns are shown of plants that received different amounts of red light energy. With increasing energy the part of the mesocotyl that is growing decreases. Also the growth of the fastest growing zones in the mesocotyl decreases. Growth in the coleoptile is progressively enhanced by red light over the whole length of the coleoptile.

Experiments with blue light (480 nm)(*fig. 4*) show that the action on growth pattern is not restricted to red light as was expected from the results of experiments on the geotropic curvature (HUISINGA 1964) .To obtain effects with blue light, comparable quantitatively with those of red light, much larger amounts of energy must be given.

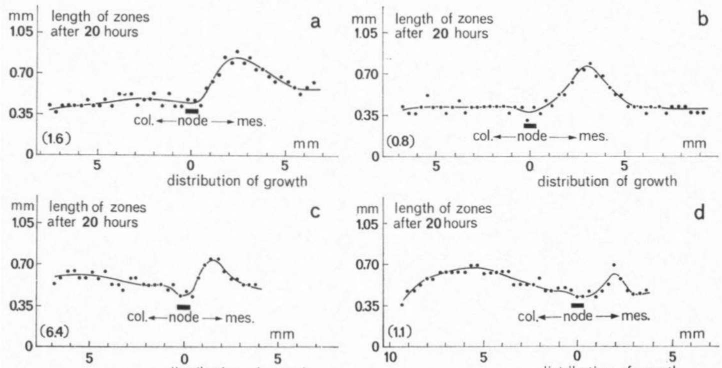

Fig. 3. Growth distribution of seedlings treated with different amounts of red (660 nm) light. a: dark; b: 100 erg/cm²; c: 1000 erg/cm²; d: 10000 erg/cm².

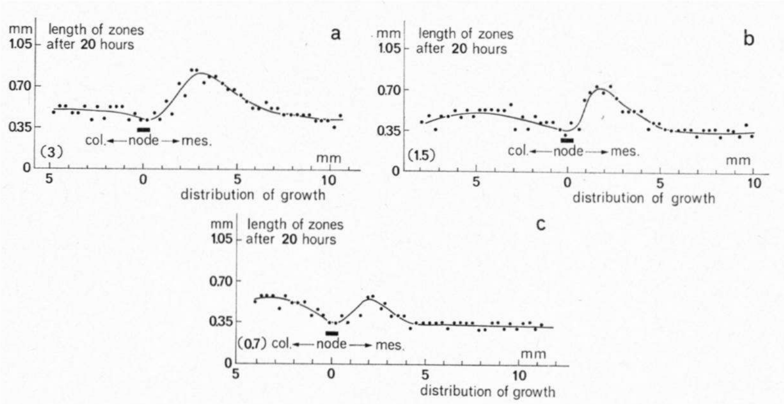

Fig. 4. Growth distribution of seedlings treated with different amounts of blue (480 nm) light.
a: dark; b: 50000 erg/cm²; c: 5000000 erg/cm².

4. DISCUSSION

From the data presented it may be concluded that the changes caused by irradiation in the shape of the geotropically induced curvature are clearly correlated with growth. This is especially clear in the mesocotyls, which miss the ability to distribute auxin laterally (HUISINGA 1964). The curved part of the plant extends downward about as far as the part of the plant in which growth can be observed. The data presented on the reactions of seedlings to different amounts of red and blue light indicate the same dependence on the wavelength and the amount of energy as did the restriction of the curving part in the experiments on geotropic curving (HUISINGA 1964).

The conclusion drawn from the observation of geotropic curvatures, that part of the influences of light on *Avena* seedlings can be explained by a decrease of transport of auxins, is supported by the observations presented on the distribution of growth in the seedlings.

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REFERENCES

BLAAUW, O. H. & G. BLAAUW-JANSEN (1964): The influence of red light on the phototropism of Avena coleoptiles. *Acta Botan. Neerl.* **13**: 541–552.

CURRY, G. M., K. V. THIMANN & P. M. RAY (1956): The base curvature response of Avena seedlings to the ultraviolet. *Physiol. Plant.* **9**: 429–440.

HUISINGA, B. (1964): Influence of light on growth, geotropism and guttation of Avena seedlings grown in total darkness. *Acta Botan. Neerl.* **13**: 445–487.

MER, C. L. & D. R. CAUSTON (1963): Carbon dioxide: A factor influencing cell division. *Nature* (London) **199**: 360–362.