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# PRELIMINARY OBSERVATIONS ON GROWTH AND PHOTOTROPIC RESPONSE OF OAT SEEDLINGS

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If oat seedlings are germinated while exposed to the continuous spectrum, the shoots in the blue region will curve toward the light source. This bending out of the plane of the spectrum is the ordinary phototropic response. In addition there appears to be a bending within the plane of the spectrum. The curvature in the blue just mentioned has components in the plane of the spectrum such that the tips of the seedlings converge. In the deep red, seedlings do not converge as in the blue, but diverge in the plane of the spectrum. In this region there is no bending out of the plane of the spectrum. There is no ordinary phototropic sensitivity (1)[1] in this region.

The components of curvature in the spectral plane seem not to be an effect of intensity gradient, but rather of a wave-length gradient, for the convergence and divergence occur on both sides of a particular narrow spectral region. It might also be the effect of a concentration gradient of a substance emanating from the seedlings. Such substances must themselves be products resulting from the effects of the radiation. The convergence occurs in the region of wave length 4,750. The divergence occurs in the region of wave length about 6,220.

As for other types of spectral response: the greatest elongational growth was in this blue region of convergence, and the next greatest in this red region of divergence. The greenest growth was in the region from 5,910 to 6,130; the yellowest from 4,356 to 5,200. Roots were longest in the extreme blue (4,356-4,800), and shortest beyond 6,200. The leaf sheath (the coleoptile) was most filled out by the first leaf in the green and orange; least filled out in the blue and deepest red regions. In the green region there appeared to be stunted growth of the coleoptile and the inner leaf broke through prematurely, but later growth in white light of seedling taken from this region was rapid. In the green, and at certain places toward the red, there appeared to be evidence of negative phototropy involving only the extreme tip of the coleoptile.

The spectrum utilized was obtained from a concave grating. The wave-length intervals throughout the spectrum are uniform. The

[1] Numbers in parentheses refer to list of literature cited at end of paper.

grating was not of the highest quality, but precautions against spurious effects from scattered light were taken by employing filters of colored cellophane.

Although the idea of forces arising from a wave-length gradient may appear strange, they are to be predicted under certain conditions. There are many varied functions performed in and by various parts of the plant. In respiratory processes, carbohydrates, fats, and proteins, water and minerals are mobilized and oxidized. In synthesis, in addition to the simple process of carbohydrate formation, there are reactions with ammonia or other nitrogen compounds, and further condensation and polymerization of the synthesized products. Also

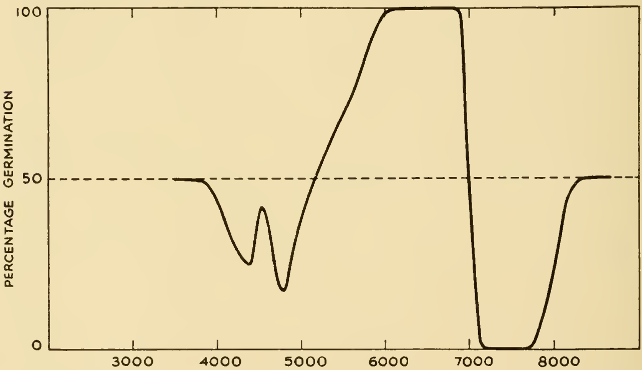


FIG. 1.—The percentage of germination (ordinates) of light-sensitive lettuce seed in different wave-length regions (abscissae) of the spectrum after an exposure to red light sufficient to effect a 50 percent germination. (From Flint and McAlister.)

the processes of transportation and storage are involved. Many different enzymes, catalysts, and hormones must be involved. Some of the processes other than the simple carbohydrate synthesis that is ordinarily thought of in connection with photosynthesis must involve external energy obtainable by thermal contact or from radiant energy of effective wave length.

Recently the effect on the germination of lettuce seed of radiant energy of various frequencies has been determined by Flint and McAlister (2). They found regions of inhibition and of activation in the spectrum of the light of the incandescent tungsten filament. The significant point is that the boundary between promoting and inhibiting regions is very sharp. (See figure 1.) If a light source had been used in which the energy in shorter wave lengths was equal to that of the longer, the steepness of slope would probably be greater on the blueward side than the curve indicates. One might expect that the seeds placed at these sharp wave-length boundaries would experience greatly different forces at various parts of their structure. If the differential action is at all translated into mechanical effects, phenomena such as the divergence and convergence noted above or twisting may be expected.

Another photic effect was observed in seeds which, after having been soaked several hours in nutrient solution, were exposed for a short time to an elevated temperature. They germinate to different extents and grow at different rates. Wet seeds exposed for 3 minutes to 40° C. are accelerated in the germinational growth, but a smaller percentage of seeds may germinate. The marked effect of exposure to 40° C. may be conditioned by the hydrolysis of starch which is promoted at that temperature (3). The effect of heating on dormancy of seeds is well known. However, if in addition to heating at different temperatures the seeds be irradiated in different parts of the spectrum, they appear to be differently sensitized to different wave lengths. Seeds subjected to the higher temperatures appeared to have greatest percentage germination in the blue, as though they were more and more dependent for germination on the blue. These are preliminary observations, but, like the photic effect first mentioned, are suggestive of a line of experimentation.

All the observations were begun at room temperatures (variable from 20° to 28° C.). Some tests for optimum temperature were initiated. Four batches of seeds, after soaking for several hours on filter paper in closed aluminum cups, were exposed for 3 minutes to 40° C. Three batches were not exposed. One of each set was kept at 25° (call these f25 and c25). Another of each was kept at 20° (call these f20 and c20). One from each set was alternated between 25° and 20° C. (f25/20, c25/20), and one (f40/20) of the first set was alternated between 20° and 40° C., being exposed twice every day for 3 minutes to a temperature of 40° C.

The longest roots and shoots, but most spindly, were in f25 (those exposed 3 minutes to 40° and kept at 25°). Next longest were in c25/20. These two also had lowest root and shoot ratio (1.2). The lowest percentage (25 per cent) of germination was in c25/20. The shortest roots and shoots were in f20/40; but greatest root shoot ratio (4.2), most hair roots, and thickest coleoptiles.

The next to the most hair roots were in f20; next to thickest coleoptiles in f25/20. Greatest percentage (76.4) germination was in f25/20.

The most growth by weight of roots and shoots of all seedlings occurred in f25/20 (15.9) and in c25/20 (14.5); least growth by weight (4.4) in f20/40; next to lowest, f25 (7.1).

All seeds were germinated in contact with nutrient solution (4), for it was found that roots function immediately as they form; and in their functioning affect immediately the growth of the seedlings with the materials they chance to meet.

The above observations were made on several occasions incidental to a study of the optimum conditions for obtaining coleoptiles of uniform reactivity phototropically. They are more a contribution to the discussion of the subject of standardization of the conditions of growth in plant physiology than announcement of new phenomena established. This study has been interrupted and the critical repetition of the observations for the time being intercepted.

The experiments, though incomplete, have led me to the following conclusion: that the conditions for optimum growth and for greater uniformity of phototropic response involve (1) contact with nutrient solution; (2) radiant energy of extended wave lengths—at least different wave lengths at different stages of growth; (3) a wave of temperature rather than constant temperature; (4) perhaps darkness as well as light; and (5) proper atmosphere.

I express appreciation to Secretary C. G. Abbot for the facilities and opportunity placed at my disposal to carry on this work, to Dr. E. S. Johnston, assistant director of the Division of Radiation and Organisms of the Smithsonian Institution, and to members of the Staff of the Division.

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