# THE DEVELOPMENT OF ROOT HAIRS. PP. 12 - 48

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# THE DEVELOPMENT OF ROOT HAIRS

A DISSERTATION

SUBMITTED TO THE FACULTY OF THE OGDEN GRADUATE SCHOOL
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BY
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# THE DEVELOPMENT OF ROOT HAIRS.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. LXXIV.

LAETITIA MORRIS SNOW.

(WITH PLATE I AND SIX FIGURES)

## INTRODUCTION.

EXPERIMENTATION upon the effect of external agents on the development of root hairs is complicated by the fact that when external conditions are varied the internal factors are disturbed by an unknown amount. The varying of only one condition, which is the essential feature in accurate research, was thus extremely difficult, if not impossible. Therefore, the results to be set forth here are understood to be tentative. The last experimental work upon the immediate subject is that of SCHWARZ (**75**), to which the reader is referred for most of the earlier literature. Apart from three or four papers, the references to the causes for the development of root hairs are found incorporated, here and there, in reports on root studies, and as a rule are merely casual observations. The work here reported has been an endeavor to add some facts and suggestions as to the causes for the production of root hairs, variations in their structure not being considered.

## LIGHT AND DARKNESS.

In view of the fact that in darkness there is generally an increase in the length of the axial organs and of their component cells (**47**, p. 64; **37**, p. 254), and because authors differ as to the effect of light and darkness upon the development of root hairs, it seemed best to reinvestigate the matter. SCHWARZ (**75**, p. 163) reports no effect; WENT'S (**85**, p. 8) experiments were not very convincing one way or another; DEVAUX (**10**, p. 306) finds that light retards growth and favors the development of root hairs; PETHYBRIDGE (**63a**, p. 235) reports that light retards the production of hairs upon the roots of oats and wheat growing in water cultures. The last experiment was repeated several times, but very little difference was noted

between the jars, the roots showing individual peculiarities of growth under both conditions. In one experiment the general growth in length seemed to be a little less in light, accompanied by a slight increase in the length and thickness of the hairs. In others no difference was noticed. No zonal arrangement was observed, as was mentioned by DEVAUX (11). According to MACDOUGAL (47, p. 246) the development of hair upon aerial organs in response to light conditions varies greatly, some plants having a tendency to decreased hair production in darkness, and others showing no change.[1]

### *A. Seedlings.*

Preliminary experiments showed that the primary roots of seedlings of *Triticum vulgare*, *Zea Mais*, *Pisum sativum*, *Cucurbita Pepo*, *Vicia sativa*, *Helianthus annuus*, *Brassica alba*, and *Raphanus sativus* produced hairs, for a longer or shorter zone, in air or water regardless of the light conditions. This is attributed by SCHWARZ (75, p. 162) to the abundant food supply, seedlings being in a measure independent of external conditions for their existence.

Seeds of wheat, corn, pea, and squash were sprouted upon moist filter paper under illuminated and darkened bell-jars. On plants of the same age the hair zones were measured. No decided difference was found, though the hair zones averaged somewhat longer in darkness. The influence of the light was not strong and was probably indirect, through its effect upon growth.

An attempt was next made to compare the increase of surface per square millimeter under the two conditions. Seedlings of sunflower, white mustard, and radish were attached to pine bars by means of filter paper and rubber bands, as described by NEWCOMBE (55, p. 150), and placed in glass jars, one set being illuminated and the other darkened. The measurements were taken in all cases, as nearly as possible in the zone of best average development, near the top of the root. The closeness of the hairs varied in different parts of the root, but the average of the numerous counts was probably not far from fair. The increase (in square millimeters) per square

[1] In connection with the experiments here reported, the condition of the hairs on the epicotyl of etiolated and normal seedlings of Helianthus were compared. In the former case the cells were longer and the hairs were not only thus farther separated, but fewer cells produced hairs.

millimeter was calculated by multiplying the average length by the average width by the average number of hairs per square millimeter by $\pi$. Scrutiny of the results in the sunflower shows that for equally long roots the increase of surface varies, but that there is a slight predominance in the average increase of plants in dark (14.8) over those in light (14.02), and that this is entirely due to the greater average number of hairs per square millimeter (395 as against 373). The individual measurements for white mustard and radish show a like fluctuation of increase, but this time with a predominance in the average of light over darkness.[2] This is probably due to the fact that these are small seeds with little reserve food, and soon begin photosynthetic work in the light, while the plants in darkness have no such advantage. No evident difference in the length of hairs was observed in dark and light, as was noted by BENECKE (**5**, pp. 28, 29) for rhizoids of Lunularia.

### *B. Older roots.*

Under ordinary conditions corn plants one or two weeks old, with roots growing through the bottom of the pots, did not produce hairs in water, whether illuminated or not. DEVAUX (**10**), on the other hand, found that light favored hair development on the roots of corn two months old growing in water. These plants, however, had been subjected to the rather severe operation of having all the roots cut off to one centimeter from the base, after which they were plunged into water. Upon repeating the experiment it was found that the plants in a day or so became yellow and unhealthy. In light five apparently healthy adventitious roots developed, and produced several isolated patches of hair, usually at the same time on all the roots, generally covered with a film of bacteria. In the darkened jar only three apparently healthy roots and two diseased ones were developed. No hairs or bacteria films appeared, although the odor of the culture betrayed greater decomposition than in the illuminated jar. Too many factors are involved to make the experiment, in its present form at least, of much value.

[2] Thus, mustard showed average increase, dark 41.33, light 44.11; and the radish, dark 29.44, light 32.09. Here also number of hairs, 321 to 344 and 345 to 357, accounts for the increase.

WENT (**85**, p, 8) found in aerial roots that light was not favorable to hair production except in very damp air, which makes it appear that with aerial roots in general moisture is of much more importance for hair development than light (PFEFFER **64**, p. 130).[3]

When seedlings of corn were allowed to send their roots through the bottom of the pots into moist chambers, one darkened and one left in diffuse daylight, little difference was observed between them, some roots in light producing more hairs and some less than those in darkness. There seemed a slight tendency for the hair to be thicker in light. MER (**51**, p. 584) found variation in the appearance of hairs on the different roots in the same culture, and considers "cette inégalité d'apparition des poils dans un même milieu est bien propre à montrer que leur développement est étroitement lié à la constitution particulière de chaque radicelle." No zonation such as DEVAUX (**11**) reports was noted in these cultures. In some cases, wheat, corn, and sunflower produced hairs in irregular zones, which however could not be traced to the effect of light and darkness. Any one of the many causes which may result in irregular growth might have been responsible. Where there is any effect on the development of root hairs produced by light, it appears from the above consideration to be due to the indirect effect upon growth. It does not appear to have the direct retarding influence as found by VÖCHTING in the case of the growth of willows and the development of new organs (**83**, pp. 152–162).

### TEMPERATURE.

The effect of high and low temperatures upon growth has been studied by many investigators (**64**, pt. 2), with the general result that increase of temperature favors growth on account of greater or more rapid absorption. KIRCHNER (**29**, pp. 353–355) reports growth increased by high temperatures; NĚMEC (**54a**) found longer, thinner cells in warm water than in cold; POPOVICI (**67**, pp. 37, 88) states that high temperatures (33° C.) diminish the zone of elongation, while low temperatures, just above the germination minimum, increase it, although the total growth is less. KOSAROFF (**32a**)

[3] For numerous instances of hair production on aerial roots touching a support, see the bibliography in WENT's paper.

and KRABBE (**33**, p. 474) found roots to absorb less water at low temperatures. VAN RYSSELBERGHE (**70a**) considers that merely the rate of absorption is affected by the impermeability of the protoplasm. DEVAUX (**11**, p. 52) considers temperature to be of great importance in the production of root hairs, but has as yet merely made that preliminary statement. SCHWARZ (**75**, p. 158) reports that optimum temperatures (27–28° C.) do not overcome the inhibitory effect of water, as the roots grow smooth.

A comparison of the increase of surface in the cases of mustard and radish shows that temperature variations of small amount have no appreciable effect. The effect of greater changes was tested with seedlings of wheat and corn. These were placed in water at temperatures of 33–38° C. No hairs appeared on the parts in water, while the parts in air, as the height of the water varied a little, produced a few hairs.

Wheat seedlings in warm water, in water at room temperature, and in cold water, grew in all three conditions, and gave the following results:

| Condition | Temperature | Duration | Result |
|---|---|---|---|
| Cold..... | 4.5–15.5° av. 11.6° (once 22.5) | Dec. 8–18 | Haired to the tip, long and close set |
| Medium..... | 16.0–29.5° av. 23.7° | Dec. 8–21 | Hairs not so good, long bare spaces at tip |
| Warm..... | 27.0–48.0° av. 34.5° | Dec. 8–14 | Only two lived, smooth |

Corn seedlings at temperatures of 29–37° (av. 33.4°) produced no hairs; while control plants at 16–27° (av. 22.9°) were haired at first, but later the root assumed its usual water type. This experiment was repeated many times with various modifications, and gave the same results.

That the smooth condition was due to the growth, rather than to the direct action of the heat upon the epidermal cells, was suggested by the following experiment. Corn seedlings were fastened in tap water of temperature 18–20° C., which was kept flowing in a very small stream from a rubber tube reaching the bottom of the jar. Under these conditions all the roots grew smooth and straight, omitting the seedling zone of hairs. Whether this was from the constant

supply of oxygen or on account of rheotropic stimulation by the rising water currents was not evident (*fig. 10*). The experiment was continued by varying the temperatures in the cold jar from 4–26°, giving very short hairs on one healthy root and on portions infested with bacteria. Once or twice a tuft of hairs was produced when seedlings were changed from cold to warm water, due possibly to retardation (ASKENASY **2,** p. 70; TRUE **80,** p. 400), but more probably to the more rapid adjustment and stretching of the epidermal cells in the warm water than of the inner cells. KIRCHNER (**29,** p. 353) found that 4° C. allowed of little or no growth of corn roots, while wheat elongated at 0°C., which may partially account for the different hair conditions in the two plants in cold water.

FIG. 10.—Corn roots growing in flowing tap water.

Wheat was planted in a pot of garden soil, and the roots allowed to come through the bottom and pass into warm water, of temperatures varying from 27–33° C. The roots were smooth at 33°, had scanty and irregular hairs at about 30°, and were more or less hairy at 27°. As this was tried repeatedly with the same result, it seems that for wheat, under these conditions, 30° C. is about the limit of hair production.

During a period of high temperature in the room, Elodea roots growing in soil were observed to be straight and smooth instead of kinky and hairy as is usual. When the temperature fell to the normal point, about 21° C., the roots assumed their usual aspect. In one case measured, the root growing in ground quartz at 27–34° C. elongated 4$^{mm}$ in five days, and was curved and piliferous. The heat was not able under these conditions to suppress hair development. Another plant of Elodea growing in a glass cylinder had accumulated a little organic matter in the bottom of the vessel, not