Botany. — *The appearance of the new physiological tip of the decapitated coleoptiles of Avena sativa.* By TSI-TUNG LI. (Communicated by Prof. F. A. F. C. WENT.)

(Communicated at the meeting of December 20, 1930).

The growth-checking effect of the decapitation on the coleoptile of Avena sativa has been very widely studied recently. Very few authors, however, carry their measurements long enough on the decapitated coleoptiles to observe the regeneration phenomenon. In 1925 SÖDING (2) extended his experiments to 18 hours after decapitation. He found that the growth rate of the coleoptile is much checked at the first five hours after decapitation, but in the last 13 hours the growth rate shows an increase of 78 %. Based on this fact SÖDING assumed that the uppermost zone of the decapitated coleoptile regains the tip function of producing the growth substance at a certain time interval after decapitation and designated this portion as the new physiological tip. His contention was confirmed by DOLK (1) in the following year.

It is rather regretful that SÖDING used such long measurement intervals as 5 hours and 13 hours. Thus his results fail to indicate the exact moment at which the new physiological tip appears. This point was studied first by DOLK. He improved on SÖDING's method by shortening the measurement interval to one hour. The result was checked by the self registered record of the auxanometer of KONINGSBERGER in a parallel series of experiments. He chose the minimum point on the growth curve after decapitation as the indication for the appearance of the new physiological tip. The results of his experiments indicate that the new physiological tip appears at 150 minutes after decapitation. The decapitated coleoptiles were kept at a constant temperature of 21° C. The length of the removed tip was 4 mm. long.

DOLK's results suggest one further problem: that is, whether this regeneration period can be changed by varying the conditions. This problem forms the subject of the present study. Three factors are here included. They are temperature, light, and the length of the removed tip. The growth of the decapitated coleoptiles is measured by the LEITZ horizontal microscope. The measurement interval is further shortened to 10 minutes.

1. *Temperature.*

In this series of experiments six lots of coleoptiles are decapitated. Each lot is subjected to a different temperature. Six temperature grades are chosen for study. They are 10°, 15°, 20°, 25°, 30°, and 35° C. The 5° grade is omitted on account of the fact that the growth rate at that temperature is so slow, and is very difficult to measure. The oat seedlings are transferred to the plant chamber in a constant-temperature water bath 3 or 4 hours before decapitation, in order to eliminate the errors introduced by the change of temperature. The length of the removed tip is 2 mm. Both decapitation and measurements are done under red light. For the rest of the time they are kept in darkness. In all temperature grades, except 35° C., a very marked growth minimum is observed on the growth curve after decapitation. In the latter temperature grade about 50 % of individuals show no such minimum. The growth declines continuously to the end of the experiment. The other half, however, show a less marked growth minimum, followed by a short period of increased growth. This probably indicates that 35° C. is the maximum temperature limit for the regeneration of the new physiological tip. The observed time period after decapitation for the occurrence of the growth minimum or for the appearance of the new physiological tip at various temperature grades are tabulated in table 1.

TABLE I. Time period in minutes for the appearance of the new physiological tip at different temperatures.

	10°	15°	20°	25°	30°	35°
Maximum time period	430′	220′	160′	110′	80′	80′
Minimum time period	360′	200′	130′	100′	80′	70′
Average time period	391′	210′	143′	101′	80′	75′
N⁰. of coleoptiles investigated	16	15	14	9	7	12

The above table clearly indicates that the moment at which the new physiological tip appears is not constant, but varies with temperature. The lower the temperature, the longer will be the required time period. The hastening effect of the raised temperature is not the same at all temperature grades, but is most marked at low temperatures. When the temperature is raised from 10° to 15°, the regeneration period is shortened by 44 %; from 15° to 20°, 32 %, from 20° to 25°, 29 %; from 25° to 30°, 20 %; and from 30° to 35°, only 6 %. Similar phenomenon was observed by MOORE (3) for regeneration in animals.

It is also interesting to note that the range of individual variation is

also reduced in high temperatures. At 10° the range of individual variation is 70 minutes, while at the three highest temperature grades it is reduced to 10 minutes.

2. *Light.*

In the second series of experiments 2 lots of coleoptiles are decapitated. One lot is subjected to a constant temperature at 20° C., while the other, at 25° C. Each individual in the two lots is exposed separately on two opposite flanks to two horizontal lights of 22 meter candle power immediately after decapitation; length of exposure 30 minutes. The results are tabulated in table 2. For the purpose of comparison the results of the unexposed decapitated coleoptiles of the same temperature grades are also added to the second table.

TABLE 2. Time period in minutes for the appearance of the new physiological tip of the exposed and unexposed decapitated coleoptiles at different temperatures.

	20° C.		25° C.	
	Exposed	Unexposed	Exposed	Unexposed
Maximum time period	160′	160′	100′	110′
Minimum time period	130′	130′	100′	100′
Average time period	142′	143′	100′	101′
N⁰. of coleoptiles investigated	25	14	3	9

It is clearly indicated on the above table that light exerts no effect on the moment for the appearance of the new physiological tip. Both the range of individual variation and the average time period are about the same in light and in darkness.

3. *The length of the removed tip.*

In the third series of experiments four lots of coleoptiles are decapitated. The length of the removed tip varies in different lots. In the first lot only 1 mm. is removed from the tip; the second lot, 2 mm.; the third lot, 4 mm.; and the fourth lot, 6 mm. All the four lots are subjected to one temperature, i.e. 20° C. These decapitated coleoptiles are all kept in darkness. A red light is used during decapitation and measurement. The results are tabulated in table 3.

TABLE 3. Time period in minutes for the appearance of the new physiological tip of decapitated coleoptiles with different lengths of removed tip.

	Length of the removed tip in mm.			
	1	2	4	6
Maximum time period	130′	160′	190′	210′
Minimum time period	110′	130′	140′	160′
Average time period	124′	143′	166′	182′
Nº. of coleoptiles investigated	14	14	15	13

The most interesting point revealed by the tabulated results is that the different zones on the coleoptile require different lengths of time period for the appearance of the new physiological tip. The zone below 1 mm. requires only 124 minutes, and the zone below 2 mm. requires 143. This period is further lengthened as the base is approached.

The second interesting point is that individual variation increases towards the base of the coleoptiles. The individual variation at the zone 1 mm. from the tip is only 20 minutes; it is increased to 50 minutes at 6 mm. from the tip.

In DOLK's (1) experiments he cut 4 mm. off the tip. From his hourly measurements he found that the growth minimum lies between 2 to 3 hours after decapitation. The record from the automatic registering auxanometer of KONINGSBERGER, however, indicates that the growth minimum occurs exactly at 150 minutes after decapitation. It is rather regretful that DOLK did not state the range of variation from the growth data of the auxanometer. The temperature used by DOLK is 21° C., which is about the same in our experiment. In comparing his result with that obtained from the 4 mm. tip class of our experiments, we find a rather close agreement. His observed result (150 minutes) lies within the range of 140 to 190 minutes in our data.

It is also interesting to note that the average minimum growth of the coleoptiles with 2 mm. tip removed is .014 mm. per 10 minutes, and that of the coleoptiles with 1 mm. tip removed is .016 mm. The averages of both classes are about the same. This seems to indicate that the zone between 1 to 2 mm. from the tip possesses no power to produce the growth substance. The function of the production of growth substance is limited to the first mm. zone of the tip of the coleoptile.

DOLK claims in his paper that the rate of growth of the regenerated coleoptiles never reach the full intensity before decapitation. However, this is only a conditional truth. Our results indicate that the length of the removed tip exerts a great influence on the growth rate of the regenerated coleoptiles. When the removed tip is only 1 to 2 mm. long the regenerated

new tip can produce enough growth substance to cause a growth rate equal to the original intensity. But when the removed tip length increases to 4 mm., the growth rate of regenerated coleoptile will never reach its former intensity. This is in agreement with DOLK's observation.

In conclusion we may say that the time period required for the appearance of the new physiological tip is not constant under all conditions. Its length depends upon the temperature and the length of the removed tip. Light exerts no influence.

A more detailed report will appear later in the Science Reports of the National Tsing Hua University, Series *B*.

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Nov. 1930.

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