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INTRODUCTION

In a former paper the author (1934) discussed the sensitivity of the *Avena sativa* coleoptile to different wave lengths of light as manifested by phototropic curvature. Maximum sensitivity occurred at wave length 4400 A, with a secondary maximum at 4750 A. From this point the sensitivity rapidly fell to a very low value at 5000 A and gradually tapered to zero between 5400 and 5500 A. Beyond this region and out into the near infrared no phototropic response was detected.

In the present paper the results of a growth study of the oat coleoptile and first internode[1] with respect to different wave-length bands of very weak light are reported. Data are also presented on some intensity effects of radiation. In all these experiments the variety Markton, obtained through the kindness of T. Ray Stanton, of the United States Department of Agriculture, was used.

As mentioned by Boysen-Jensen (1936), the elongation of the first internode has been attributed to numerous factors such as low temperature, low soil moisture content, and high carbon-dioxide content of the atmosphere. Several experimenters have shown that the elongation of the first internode can be suppressed by illuminating the seed when it is in a moist condition. One should, therefore, expect to obtain short first internodes on growing oat seedlings in light and long first internodes when they are grown in darkness. This raises

[1] According to Avery (1930), the elongated structure between the cotyledon and the coleoptile in oat seedlings is the first internode of the axis. He regards the term " mesocotyl ", as applied to this structure, meaningless. The term " first internode " is the author's preference, although, in discussing the work of others, " mesocotyl " is sometimes used.

the question as to what differences, if any, may occur in the length of the first internode when the seedlings are subjected to different wave-length bands of the visible spectrum.

EXPERIMENTATION

First series (with Mazda lamp).—Two Bausch and Lomb quartz monochromators were set up in tandem to obtain the desired isolated regions of the spectrum. A 1000-lumen, 1.6-ampere street-series lamp served as the light source. A small mirror reflected the beam of light onto the young plants. The intensity was adjusted to 1.2 ergs/cm^2/sec. at the position of the seeds. The dry seeds with the chaff removed were placed on a moist medium in a moisture chamber

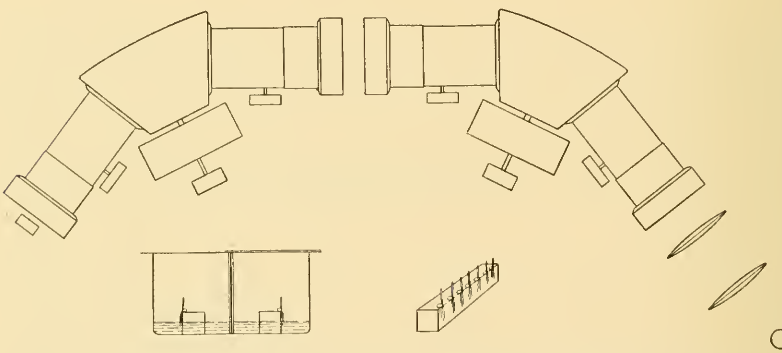

FIG. 1.—Diagram showing general arrangement of monochromators and position of seeds on "germination wick" in moisture chamber.

and allowed to remain undisturbed for a period of four days. The moist medium on which the seeds were placed was filter paper saturated with distilled water. This system was used for the first 16 experiments. It was not always possible to get the same degree of moisture, and certain irregularities in germination occurred. This system was discarded in favor of one in which the Livingston solid wick mentioned by Norem (1936) was used. These porous stone pieces were cut 1 inch square and 4.5 inches long. After they were moistened with distilled water a piece of wet filter paper was wrapped around each. They were then placed in a moisture dish containing about ½ inch of water. The seeds were laid, groove side down, along the edge with the base end extending slightly over the edge. The roots attached themselves to the filter paper and grew down into the water. After the first 24 hours in darkness they were irradiated continually for three days with monochromatic light. (See fig. 1.)

A set of similar seeds was grown simultaneously in darkness for the entire period of four days. In the first nine experiments the dark controls were grown in a separate container. For the other experiments of this series the dark controls were grown in the same container with the illuminated plants but were separated from them by a black paper partition held between two pieces of glass. The top of the chamber was covered with a piece of glass and the entire top area, as well as the sides, covered with black paper and cloth, except for the opening, which permitted light to reach the exposed set of plants. Subsequent experiments showed that even these precautions to keep light from reaching the dark control plants failed. Examination of data in table 3 clearly shows that the dark controls in the same chamber with the exposed plants must have received some scattered light because of their differences in growth. Because of this scattered light effect the dark controls with the exception of the first nine experiments in the first series are of little value.

An experiment for each wave-length setting was repeated at least once. At the end of each 4-day experiment the lengths of coleoptiles and first internodes were determined. Because of the restricted size of the light beam coming from the monochromator the number of seeds exposed was limited to about seven without too great crowding. Occasionally a seed or two failed to germinate, and sometimes something happened that justified the elimination of others. For the entire series of experiments the average number of seedlings in each exposed group and each dark control was six. Since each experiment was repeated, this at least doubled the number of seedlings for each wave-length setting.

The experiments were conducted in a small room with no outside walls. The lamp was located in another room, so that after an experiment was started no entrance was made to this room until its conclusion at the end of four days. Because of the location of this room in the basement of the Smithsonian Building, the temperature variation was exceedingly small. Seldom was the difference between maximum and minimum temperature greater than 2° F. for any of the 4-day periods. Once there was a 4° difference and twice a 3° difference. The average maximum and minimum temperatures for the 36 different experiments were 75° F. and 74° F., respectively.

The average lengths (mm) of the first internode, coleoptile, and total oat seedling of each 4-day experiment are presented in table 1. For each wave length the data of at least two experiments are given. The last two columns show the maximum and minimum temperatures (° F.) for each experiment. It will be noted that there is fairly good agreement between the duplicate experiments of the exposed series. The greatest discrepancies occur for wave lengths 5195 A and 5403 A. In the dark series of experiments there is considerable variation between the averages of similar experiments. This is especially noticeable for those corresponding to wave lengths 4050 A, 4405 A, and 5403 A. For example, there appears to be no good reason why the dark experiments corresponding to those of wave length 4405 A should give an average for the first internode of 59 mm in one case and 34 mm in the other. The temperature ranges were exactly the same, 76°–75° F. There is the possibility that the filter paper medium here used was drier in one experiment than in the other. The dark controls of the first nine experiments were in a different container than those of the exposed series. It would appear from this example and general observations throughout all the experiments that individual variations are enhanced when the oat seedlings are grown in the absence of light.

The growth data of table 1 are diagrammatically represented in figure 2. The ordinates represent length in millimeters. Similar experiments are grouped together with the wave length designated below. In the series exposed to light the first internodes are represented by the dotted sections and the coleoptiles by the clear sections. In the dark series the shaded portions represent the first internodes and the hatched portions the coleoptiles.

The most striking feature of this diagram is that for all wave lengths the first internodes of the exposed plants are always shorter than the first internodes of the corresponding dark control plants. There is not a single experiment in which this is not the case. Even in wave length 7600 A, which was scarcely visible to the eye, the lengths of the first internodes of the exposed plants are depressed. Data from experiments not shown here but carried out several months earlier, covering the range of wave lengths whose average was 7600 A, were very similar to those here presented. Another feature that this diagram clearly shows is that the coleoptiles of all the dark experiments are short in comparison to the coleoptiles in the exposed series. Here again there are no exceptions. Furthermore at the end of the 4-day periods the total length of seedlings in the dark series of experiments is somewhat greater than the total length of seedlings in the exposed series. There are a few exceptions. The average total length of seedlings in the former group is but 7 mm greater than the total length of the latter or exposed group. This would indicate that the total growth attained in a 4-day period was not greatly influenced by light. If growth depends on the amount of growth substance present, it would indicate that light of this low

TABLE 1.—*Data Showing Average Length (mm) of First Internode, Coleoptile, and Total Oat Seedling (Avena sativa var. Markton) After Four Days' Growth in Light and in Darkness at the Indicated Maximum and Minimum Temperature (° F.)*

Wave length A	Exposed series			Dark series			Temperature	
	First internode	Coleoptile	Total	First internode	Coleoptile	Total	Max.	Min.
4050	30	30	60	75	10	85	77	76
	30	29	59	47	6.	53	79	77
4265	31	30	61	51	6	57	79	77
	29	26	55	65	9	74	78	78
4405	29	23	52	59	6	65	76	75
	30	27	57	34	6	40	76	75
4595	24	24	48	64	8	72	78	77
	27	22	49	55	8	63	76	76
4798	30	21	51	59	7	66	76	75
	27	25	52	54	11	65	88	88
5005	30	24	54	59	11	70	73	72
	30	28	58	61	9	70	73	72
5195	32	26	58	55	9	64	74	72
	29	31	60	60	12	72	75	72
	25	30	55	56	10	66	74	73
5403	28	30	58	56	11	67	73	72
	30	31	61	57	18	75	74	73
	23	22	45	42	11	53	72	71
5605	22	22	44	37	9	46	73	72
	19	19	38	40	10	50	74	72
5795	22	26	48	46	15	61	74	73
	19	28	47	39	15	54	74	72
5990	17	23	40	44	14	58	74	72
	21	27	48	43	18	61	74	72
6200	18	20	38	35	12	47	74	73
	15	23	38	43	16	59	64	62
6395	16	29	45	42	16	58	75	72
	19	34	53	39	19	58	75	73
6595	15	27	42	33	17	50	74	72
	17	31	48	33	14	47	75	73
6800	24	35	59	40	20	60	76	74
	20	38	58	38	23	61	74	72
7005	24	34	58	36	19	55	75	74
	25	32	57	35	16	51	76	75
7600	33	28	61	41	7	48	76	74
	32	25	57	51	9	60	78	74

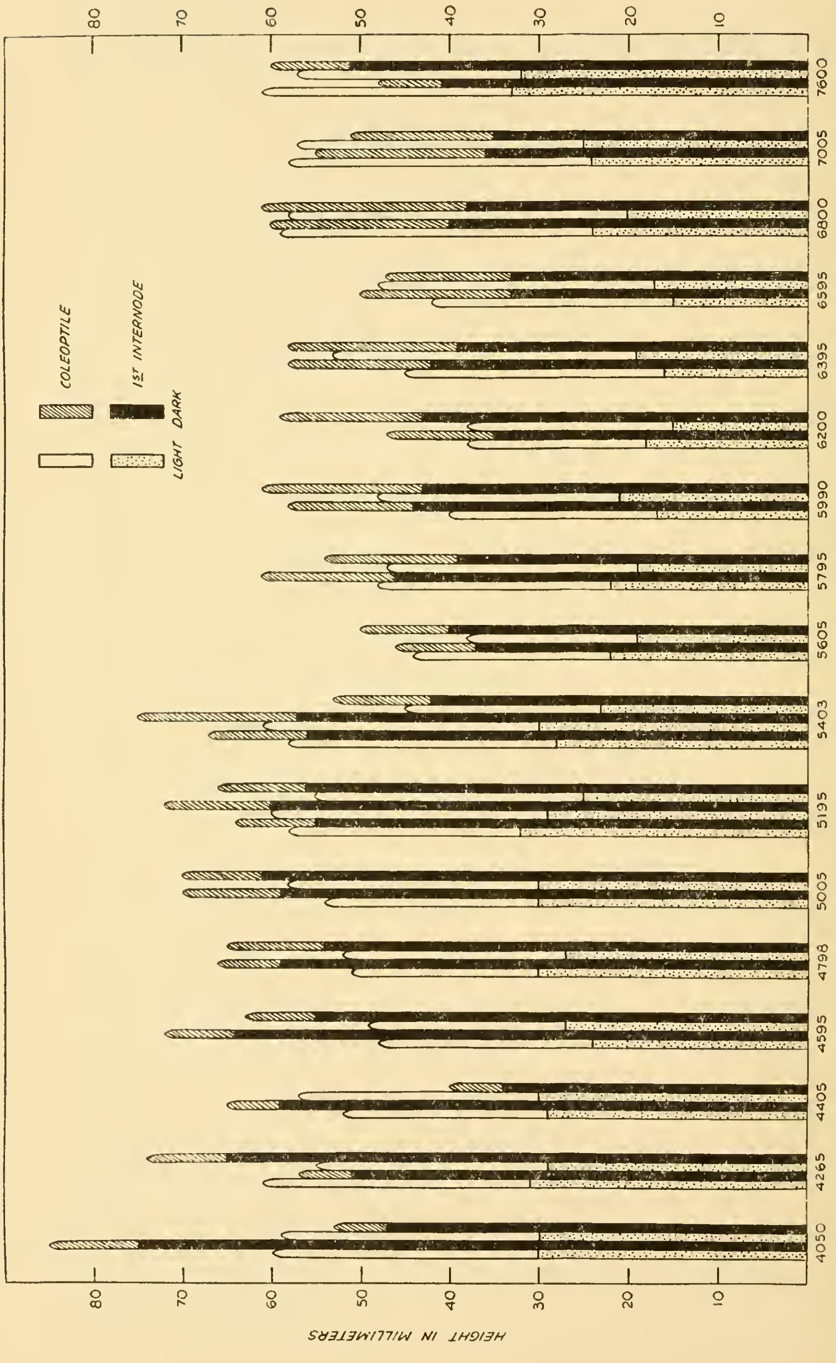

FIG. 2.—Diagram representing growth of oat seedlings in different wave-length regions of the spectrum. The coleoptiles are shown as clear and hatched areas for the exposed and dark controls respectively. The first internodes are shown as dotted and blackened areas for the exposed and dark controls respectively. The lengths as ordinates are given in millimeters, and the center of the wave-length bands in angstrom units.

intensity acts as a factor redistributing these substances. This is evidenced by differences in lengths of first internodes and coleoptiles of exposed and darkened series of plants. If the total amount of growth substance were changed at all, there is the suggestion that a smaller amount is present in plants exposed to light than in plants kept in darkness.

The ratio of the length of the first internode to the total length of seedling was determined for each plant and averaged for each experiment and again averaged for the corresponding wave-length group. These data are presented in table 2. There is surprisingly small variation between the duplicate and triplicate experiments. There was such small variation between the different seedlings of a given group that the first internode was found to be a fairly definite percentage of the total length of the seedling regardless of whether the seedling was long or short. In the exposed series, the average ratio values vary from a maximum of 0.56 for wave-length regions 4798 A, 5005 A, and 7600 A to a minimum of 0.36 at wave-length regions 6395 A and 6595 A. In the dark series the average ratio values vary from 0.89 in the first two wave-length experiments to 0.65 in the third from the last experiment.

The natural question to be asked is why should the ratio of the dark controls vary to that extent especially since the temperatures (see table 1) of these different experiments were about the same. If it were a matter of total growth alone, then it is to be expected that the seedlings of the first two experiments would be longer because of a higher average temperature. As previously mentioned, the dark-control plants of the first nine experiments were grown in a separate growth chamber where there was no possibility of scattered light reaching the young plants. The ratio values of the other dark control experiments are, in general, lower, especially for wave-length regions 5403 A to 7005 A, inclusive. Here a partition of black paper held between two glass plates separated the exposed from the darkened seedlings.

To correct the ratio values for differences in temperature, atmospheric conditions, and viability, each exposed value was divided by the corresponding dark value. These are recorded in the sixth column and the average for each wave-length group placed in column 7. However, since the dark control values (except the first nine) appear not to be true values because of scattered light, all the average ratio values (exposed/dark control) have been made relative to the average of the first nine dark control ratios (0.89). These have been placed in the last column of table 2.

Table 2.—*Average Ratio of Length of First Internode to Total Length of Seedling for Each Experiment and for Each Wave-Length Region in the Exposed and Dark Series*

Wave length Å	Exposed series	Average	Dark series	Average	Ratio exp./dark	Av. ratio exp./dark	Ratio av. exp. to av. dark (0.89)*
4050	.50		.89		.56		
	.52	.51	.89	.89	.58	.57	.57
4265	.51		.90		.57		
	.53	.52	.88	.89	.60	.59	.58
4405	.55		.90		.61		
	.53	.54	.85	.88	.62	.62	.61
4595	.51		.89		.57		
	.55	.53	.86	.88	.64	.61	.60
4798	.59		.90		.66		
	.52	.56	.83	.87	.63	.65	.63
5005	.55		.85		.65		
	.56	.56	.88	.87	.64	.65	.63
5195	.55		.85		.65		
	.48		.84		.57		
	.47	.50	.85	.85	.55	.59	.56
5403	.47		.83		.57		
	.49		.76		.64		
	.52	.49	.79	.79	.66	.62	.55
5605	.50		.80		.63		
	.49	.50	.81	.81	.61	.62	.56
5795	.45		.75		.60		
	.41	.43	.71	.73	.58	.59	.48
5990	.42		.76		.55		
	.45	.44	.71	.74	.63	.59	.49
6200	.46		.74		.62		
	.39	.43	.72	.73	.54	.58	.48
6395	.36		.73		.49		
	.36	.36	.66	.70	.55	.52	.40
6595	.36		.67		.54		
	.36	.36	.69	.68	.52	.53	.40
6800	.41		.67		.61		
	.34	.38	.62	.65	.55	.58	.43
7005	.42		.65		.65		
	.45	.44	.69	.67	.65	.65	.49
7600	.55		.84		.65		
	.56	.56	.85	.85	.66	.66	.63

* In the first nine dark experiments the seedlings were grown in a separate moist chamber. Since there was no possibility of exposure to stray light, the average ratio of first internode to total length for these nine experiments has been used as unity in determining the values in the last column.

In order to visualize these ratio values, figure 3 has been constructed. The average ratio value of first internode to total length per wave length is indicated by the dash curve (L). The corresponding dark values are shown as the continuous curve (D). It will be noted that in the exposed series there is a fairly consistent drop in the curve from about 5000 A to the region 6400–6600 A. From this region the curve rises to a second maximum at 7600 A. The dark control curve shows much the same shape, and this would indicate that some stray light or some common external factor was affect-

FIG. 3.—Graphs showing the average ratio values of first internode to total seedling length per wave-length region of the exposed series (L) and the corresponding average ratio values of the dark series (D). The ratio values of the exposed series divided by the corresponding values of the dark series are plotted as curve R. T is the average temperature curve.

ing the growth of the first internode. If it be assumed that all external growth conditions be the same in the two series with the exception of light, then the effect of light is shown by dividing the values of the exposed series by those of the dark series. The values in column 7 of table 2 have therefore been plotted in figure 3 as the dash-dot curve (R). This curve shows a distinct falling off in the region 6400–6600 A, with two maximal regions 4800–5000 A and 7600 A.

Since it is probable that there were some scattered light effects in all but the first nine experiments of the dark series, curve L probably gives a better idea of the light response of the first internode as related to total length of seedling than curve R. It is doubtful if temperature differences were great enough to bring about marked variations in growth rates. The average temperatures for each wave-length group are plotted as the dotted curve (T) in figure 3.

The average ratios of coleoptile to total length of seedlings are not given in table 2, but they may easily be obtained by subtracting the values in the third column from 1.00. The shape of the curve

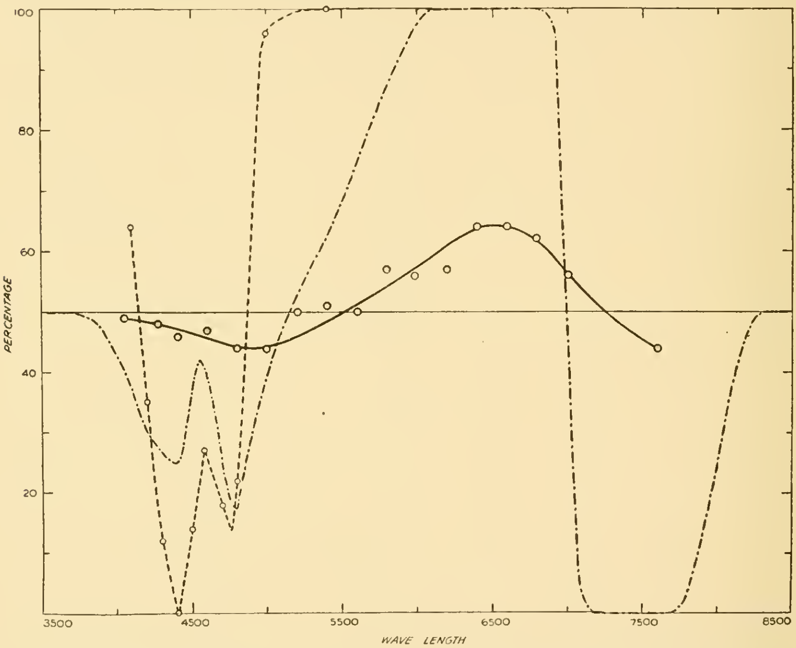

FIG. 4.—Graph showing percentage of coleoptile to total length of seedling of exposed series (continuous curve). For comparison the germination curve (dash-dot) of light-sensitive lettuce seed (from Flint and McAlister) and the inverted phototropic sensitivity curve (dash) of *Avena* (from Johnston) are plotted in the same figure.

is that of the mirror image of curve L in figure 3. This smoothed coleoptile curve has been plotted in figure 4 as a continuous line. It will be observed that from wave length 4050 A to 5500 A the ratio values are less than 0.50. In this region the coleoptile is less than 50 percent of the total seedling length. Furthermore, the length of coleoptile is greater than 50 percent of the seedling length from about wave length 5500 A to wave length 7200 A. Maximum coleoptile elongation occurs at the region 6400 A to 6600 A with a minimum at about 4800 A to 5000 A and another in the region of 7600 A.

The similarity of this curve to that found by Flint and McAlister (1935, 1937) representing the germination of light-sensitive lettuce seed was so marked that their curve has been plotted as the dash-dot line in this same figure. The general similarity of these two curves is suggestive of a common physiological process. The retarding action of radiation on growth in the region 4000 A to 5000 A is likewise seen by inverting the phototropic sensitivity curve found by Johnston (1934) and plotting it as the dash curve in figure 4. In the phototropic studies, however, no acceleration in growth was noted in the region 6000 A to 7000 A as would have been indicated by negative bending. This lack of response may be due to an insufficient light gradient in this region.

Second series (with mercury lamp).—In the experiments so far described, the wave-length bands averaged in width about 300 angstroms. By using a capillary high-pressure mercury lamp (H–3 type) as the light source, a greater amount of energy could be directed on the plants and most of the energy concentrated in the mercury line selected for the exposure. In the second series of experiments four mercury lines were used. The intensity at the beginning of each experiment was set at 13 ergs/cm^2/sec. This intensity sometimes dropped as low as 7 ergs/cm^2/sec. at the end of the experiment because of the creeping of the lamp in its socket. However, it was still considerably higher than that in the first series (1.2 ergs/cm^2/sec.).

Two dark controls were run with each set of exposed plants. One control was in the same moisture chamber with the exposed plants but separated from it by a black partition, as was the case in the first series of experiments. The other dark control was placed in another moisture chamber wrapped with black paper and covered with a black cloth. Here there was no opportunity for exposure to scattered light. Each wave-length experiment was run three or four times with an average of six seedlings for each run of the three conditions. Data showing the average length of first internode, coleoptile, and total length of seedlings after four days of growth are presented in table 3. The maximum and minimum temperatures are also included in the table. The average data for each wave length are shown in boldface type.

In the exposed series, the first internodes were always shorter than the coleoptiles. In the dark-control series in the same chamber with the exposed, the first internodes were always longer than the coleoptiles, while in the other dark control, where no light of any kind could reach the seedlings, the first internodes were very much longer than the coleoptiles. These differences in lengths of first internode and coleoptile clearly show the marked effect of light. Even the dark-control plants exposed to a minute amount of scattered or diffused light showed that the seedlings are extremely sensitive to light. It is rather remarkable that such small amounts of radiation should completely change the relative length of first internode and coleoptile.

TABLE 3.—*Data Showing Average Length (mm) of First Internode, Coleoptile, and Total Oat Seedling After Four Days' Growth in Light (Approximately 13 to 7 ergs/cm²/sec.) of Mercury Lamp and in Darkness, at the Indicated Maximum and Minimum Temperature (° F.)*

[Average Data in Boldface Type]

Wave length	In same moisture chamber						Separate chamber			Temperature	
	Exposed			Dark control			Dark control				
A	Int.	Col.	Total	Int.	Col.	Total	Int.	Col.	Total	Max.	Min.
4047	15	27	42	22	10	32	..	..	..	75	74
	20	45	65	45	21	66	..	..	..	79	76
	24	23	47	..	..	..	48	7	55	79	76
	25	35	60	48	15	63	73	11	84	78	77
	21	**33**	**54**	**38**	**15**	**54**	**61**	**9**	**70**	..	..
4358	26	40	66	51	16	67	66	11	77	79	77
	25	38	63	52	16	68	66	11	77	78	76
	25	34	59	47	13	60	60	8	68	78	77
	25	**37**	**63**	**50**	**15**	**65**	**65**	**10**	**74**	..	..
5461	20	32	52	39	15	54	63	8	71	77	76
	14	21	35	33	13	46	57	7	64	76	76
	20	28	48	38	13	51	48	7	55	75	75
	20	39	59	43	17	60	55	10	65	79	78
	19	**30**	**49**	**38**	**15**	**53**	**56**	**8**	**64**	..	..
5780	17	49	66	45	36	81	61	10	71	79	78
	19	47	66	47	31	78	50	8	58	80	79
	20	46	66	45	28	73	67	10	77	78	78
	19	**47**	**66**	**46**	**32**	**77**	**59**	**9**	**69**	..	..

The average total seedling lengths for the three series are 58, 62, and 69 mm, corresponding to the exposed, "diffused" control, and totally dark control, respectively. Here again the effect of light is noticed. The total length is greatest in complete darkness, less in the presence of minute scattered light, and least in the illuminated series. Although the total length is not greatly changed by light, as was true in the first series of experiments, yet there is a distinct indication that total growth is less and that the activity of growth substance or regulators is slightly decreased even by very weak light.

The marked differences in relative lengths of first internode and coleoptile in the dark and exposed series indicate some drastic redistribution of growth regulators.

The ratios of first internode and of coleoptile to total length of seedling are shown as percentages in table 4. These percentages were determined for each seedling and then averaged for each experiment and again averaged for each wave length. This last average is shown

TABLE 4.—*Percentage Length of First Internode and Coleoptile of Total Length of Avena Seedling for the Designated Wave Lengths and Temperatures*

[Average Data in Boldface Type.]

Wave length	In same moisture chamber				Separate chamber		Temperature (° F.)		
	Exposed		Dark control		Dark control				
A	Int.	Col.	Int.	Col.	Int.	Col.	Max.	Min.	Average
4047	36	64	68	32	..	..	75	74	74.5
	31	69	69	31	..	..	79	76	77.5
	51	49	..	..	88	12	79	76	77.5
	42	58	76	24	87	13	78	77	77.5
	40	**60**	**71**	**29**	**87**	**13**	..	..	**76.8**
4358	38	61	76	24	86	14	79	77	78.0
	40	60	76	24	86	14	78	76	77.0
	43	57	78	22	88	12	78	77	77.5
	41	**59**	**77**	**23**	**87**	**13**	..	..	**77.5**
5461	38	62	73	27	88	12	77	76	76.5
	39	61	73	27	89	11	76	76	76.0
	41	59	74	26	87	13	75	75	75.0
	34	66	72	28	85	15	79	78	78.5
	38	**62**	**73**	**27**	**87**	**13**	..	..	**76.5**
5780	25	75	56	44	86	14	79	78	78.5
	29	71	60	40	87	13	80	79	79.5
	30	70	61	39	87	13	78	78	78.0
	28	**72**	**59**	**41**	**87**	**13**	..	..	**78.7**

in boldface type. Temperature data are given in the last three columns. But little difference is to be seen in the percentages of lengths of first internodes and coleoptiles in the first three wave lengths. The values for 5780 A are, however, different. A comparison of these percentage values in the two series of experiments for the exposed coleoptiles is shown below. The wave-length values between the two series are not strictly comparable but are approximately correct.

Each set of values shows about equal lengths of coleoptile for the first three wave-length values. The value for the 5780 A region of each series is higher. All values in the second series of experiments are higher. If it is assumed that the small temperature differences between the various experiments exert but little influence, then it must be concluded that the increased intensity in the second series of experiments has increased the percentage length of the coleoptile. This

TABLE 5.—*Comparison of Percentage Length of Coleoptiles in the Two Series of Experiments for Corresponding Wave Lengths*

Wave length A	First series Percent	Second series Percent
4047	49	60
4358	48	59
5461	51	62
5780	57	72

is in agreement with the observation that the coleoptiles were longest in the exposed series (greatest intensity), shortest in the completely darkened series (zero intensity), and intermediate in length in the dark control exposed to very diffused light. The reverse is true regarding the first internodal values, which are the coleoptile values subtracted from 100.

DISCUSSION

In determining the sensitivity curve (Johnston, 1934) of *Avena* coleoptile, only the tips were illuminated. In the experiments here reported entire seedlings were grown in restricted wave-length regions of the spectrum. Went (1926) has pointed out two distinct light responses in the coleoptile, one the tip response, the other the base response. Where the entire coleoptile is illuminated, both responses are concerned. Van Overbeek (1936 b) calls attention to a third type of response described by Tollenaar and by Van Dillewijn, which is designated as the " dark growth response." It is the increased response to growth substance in darkness and has nothing to do with bringing the plants back into darkness. Plants continuously exposed show the response.

In the present experiments the time period was exactly four days, and in that length of time the first internode as well as the coleoptile attained considerable length. The light response of both organs must be considered as well as their interactions. Also the seed and roots in the exposed series received a certain amount of radiation. The problem becomes further complicated when the action of plant growth substances with their production, inactivation, and transport is considered.

Du Buy and Nuernbergk (1934) report an experiment in which monochromatic light of higher intensity (170, later 80 ergs/cm²/sec.) was used. The mercury arc and incandescent lamp with appropriate glass and liquid filters were used. After six days the following lengths of first internodes and coleoptiles are given:

TABLE 6.—*Length of First Internode and Coleoptile in Monochromatic Light (After Du Buy and Nuernbergk)*

Wave length A	First internode (mesocotyl)	Coleoptile	Total length
3663	13.5	39.5	53.0
4358	18.3	44.3	62.6
5461	19.7	51.2	70.9
6000	19.6	46.4	66.0
Dark control	22.5	50.3	72.8

At the end of four days the average length of mesocotyl under each of the five different treatments was given as 1.5. Under the four conditions of illumination, the coleoptile varied in length from 22 in the ultraviolet to 26.6 in the red. The dark value given for the coleoptile was 12.5, approximately half that of the exposed values. At the end of the third day no growth of the mesocotyl was detected. By the sixth day in these experiments the primary leaf had broken through in 90 to 100 percent of the seedlings. In the Smithsonian experiments the primary leaf was usually at or near the top of the coleoptile but had never broken through in the plants of either the exposed or the dark series. From the above table it will be noted that the first internode or mesocotyl of the dark control was longer than those of the illuminated seedlings. The coleoptile was also longer with one exception than those of the exposed seedlings. The reason for this disagreement with our experiments is not clear unless it may be due to a difference in oat varieties used. In the Smithsonian experiments the coleoptiles of the dark controls were always shorter than those of the exposed plants. This was also true on the fourth day in the experiments of Du Buy and Nuernbergk. At the end of six days, with the exception of the group exposed to 3663 A, there is but little difference in total length of seedlings. Here also the total length of their dark control is slightly greater than those of the exposed series.

Du Buy and Nuernbergk (1935) give two explanations as to why growth of the mesocotyl is depressed. First, according to their theory, protoplasmic streaming is correlated with the activity of growth regulators. Temperatures above 25° C. and illumination retard protoplasmic streaming. The cells of the coleoptile will, therefore, retain more growth regulators than are transported to the mesocotyl cells at high temperatures and when illuminated. Hence, under such conditions the coleoptile grows faster than the first internode or mesocotyl. The length of path that the growth substance must travel to reach the cells of the mesocotyl is thus increased and less growth in this latter tissue will result. Their data (1934) and those of Hamada (1931) show, as one would expect from this theory, the mesocotyl cells of illuminated plants to be smaller than those of dark-grown plants. A second explanation is that mentioned by Van Overbeek (1935), who states that a temporary increase in temperature increases the use of auxin, thereby decreasing the amount available to the mesocotyl. According to DuBuy and Nuernbergk (1935), it is very probable that a decreased protoplasmic streaming and an increased use of auxin together cause an increased growth of the coleoptile and a decreased growth of the mesocotyl. The reaction capacity of cells to growth substances may also enter into the problem since such reaction capacities appear to be different for light and for dark exposed plants, as shown by Du Buy (1933), and for plants grown under different humidity conditions, as shown by Gorter and Funke (1937).

The results of several experimenters show that the growth of the first internode may be depressed by light, high temperatures, and decapitation of the coleoptile tip. Van Overbeek (1936 a) depressed mesocotyl growth of maize seedlings by exposure to a temperature of 48° C. for half an hour. The amount of growth substance taken from the tips of similarly treated seedlings was less than that from the controls. That there is a linkage between the amount of growth substance obtainable from the tip of the coleoptile and the growth of the first internode seems evident. It is reasonable to suppose than any condition that would inactivate the growth substance in the tip of the coleoptile or that would interfere with its transport to the first internode would depress the growth of the first internode. From the data here presented, it would appear that radiant energy, even as low in intensity as 1.2 ergs/cm^2/sec., has a very definite influence. Whether this influence is exerted through a direct effect on the growth substance itself or on its mode of transportation through protoplasmic streaming or other means cannot be stated. There also appears to be a wave-length effect. But whether this is a direct effect on the first internode or a secondary one through its action on the coleoptile, which in turn would control the growth substance reaching the first internode, cannot be concluded from these data. Under one set of conditions (darkness) the first internode is long and the coleoptile short. Under other conditions (illumination) the first internode is short and the coleoptile long. It would appear that in the first case the growth substances were not utilized for growth in the coleoptile, but transported to the first internode where the greater amount of growth was found. In the second case considerable more growth took place in the coleoptile. Here it would appear that some growth substance was prevented from acting on the cells of the first internode. In these experiments light was evidently the controlling factor in the distribution of the growth substance.

Reference to figure 4 shows that wave lengths 4050 A to 5500 A slightly depressed the growth of the coleoptile. In this region growth of the first internode was somewhat increased. In the wave-length region 5500 A to 7200 A the reverse effect is noted. Here the coleoptile growth is increased and that of the first internode decreased. Since there is very little difference in total growth of the entire seedling between light and dark conditions, one is led to the conclusion that light of this low intensity functions mainly as a distributing rather than an inactivating factor on growth substance. However, since there was actually a slight difference in total growth, there may also be a slight inactivating influence of light, for the experimental data show slightly greater average growth for the dark control plants than for the illuminated ones.

SUMMARY

Two series of experiments were conducted in which the growth of the coleoptile and first internode (mesocotyl) of *Avena sativa,* Markton variety, was studied in different wave-length regions of the visible spectrum.

Radiation of low intensity greatly depressed the growth of the first internode as compared to that in darkness. On the other hand, growth of the coleoptile was depressed in darkness. Total growth of the entire seedling (coleoptile plus first internode) for the 4-day periods of all these experiments was slightly greater in darkness than in light. Although the total length of seedling was not greatly dependent on intensity of illumination, the ratios of first internode and coleoptile to total length were extremely critical indices to intensity of illumination. It is extremely difficult to get conditions dark enough to avoid light effects on these ratios.

All wave lengths give much the same tendency to decrease the ratio of first internode to total length and this effect increases with light intensity. Yet there is a wave-length effect yielding a minimum ratio at about 6500 A.

It would appear that growth of the coleoptile retards the growth of the first internode and that the growth of the one tissue takes place at the expense of the other. Light probably acts more as a redistributing agent of the growth substances than an inactivating agent. However, even at the low intensities here employed, there was a slight indication that some inactivation occurred, since the average total length of the illuminated seedlings was slightly less than that of the dark controls.

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