

CONCERNING THE INFLUENCE OF POLARIZED LIGHT ON THE GROWTH OF SEEDLINGS.

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The biological effects of polarized light have, until a year or two ago, not been the subject of any scientific experimental study. Recently a few contributions on the subject have appeared. Baly and Semmens published a short note describing the stimulating effect of polarized light on the hydrolysis of starch by diastase (1). These observations were confirmed by the present author (2) who at the same time published several short communications on the pharmacological and other biological effects of polarized light (3) and also described in collaboration with Justina Hill some experiments on the growth of yeast and bacteria (4). In this last communication, Miss Hill and the author called attention to the apparent stimulation of bacterial growth by polarized light. Similar observations on bacteria were published independently by Morrison (5), and recently two Indian investigators have also published a short note claiming that the bacteria of typhoid fever and cholera thrive better in polarized light than in non-polarized light (6). In the present paper the author proposes to describe a series of experiments on the growth of seedlings in polarized and non-polarized light which were begun early in 1924 and continued up to the present time.

Method.

The growth of young seedlings of *Lupinus albus* in a nutrient physiological (Shive's (7)) solution was followed by measuring the elongation of the roots at intervals of 24 hours. The influence of polarized and non-polarized light was studied by means of the following apparatus which was designed jointly by the author and Professor

A. H. Pfund of the Department of Physics of the Johns Hopkins University and was constructed under Professor Pfund's supervision and calibrated by him. A box or cell in the form of a truncated pyramid was constructed 80 cm. high, with a lower base 60×45 cm. and upper end about 25 cm. square, the back of the wall of the cell being perpendicular to the base, and the front wall and *door* being slanting. At the upper or small end of the cell a socket is fixed into which is inserted a large round Mazda tungsten nitrogen electric bulb, of 500 watts power, which serves as a source of light. The lower part of the apparatus or cell is divided into two compartments, completely separated from each other by a blackened partition. The light of the Mazda lamp is allowed to penetrate into the chamber on one side of the apparatus after first passing through a dozen plates of smooth glass, placed at the "polarizing" angle, so that this chamber is illuminated with highly polarized light. The light from the same Mazda lamp, on the other hand, is allowed to penetrate into the second or neighboring chamber after first passing through a pile of smooth plates of glass placed *perpendicular* to the line of propagation of the light, so that this second chamber is illuminated with non-polarized light. The number of glass plates in this second pile was adjusted so that the intensity of the non-polarized light was just equal to the intensity of the polarized light in the first chamber. By boring apertures in the floors of the two respective chambers and taking spectrographs of the two transmitted lights, it was found that the spectral range of light waves in the polarizing and non-polarizing chambers was the same, the shortest waves transmitted being about 3650 Ångstrom units. The temperatures in the two chambers were nearly the same, not deviating from each other more than 0.5°C .

The source of light was an electric bulb of 700 candle power. This intensity was of course cut down by passage through the piles of plates, but the intensity of the transmitted light in each chamber was made the same by photometric calibration in the Physics Laboratory, performed by Professor A. H. Pfund. The intensities in the two chambers were compared by Professor Pfund by reflecting the lights passing through the two sets of glass plates, from a white surface, and allowing the rays to pass through a Lummer tube. The light from the two chambers was thus reflected *diffusely*, and hence was *depolarized*

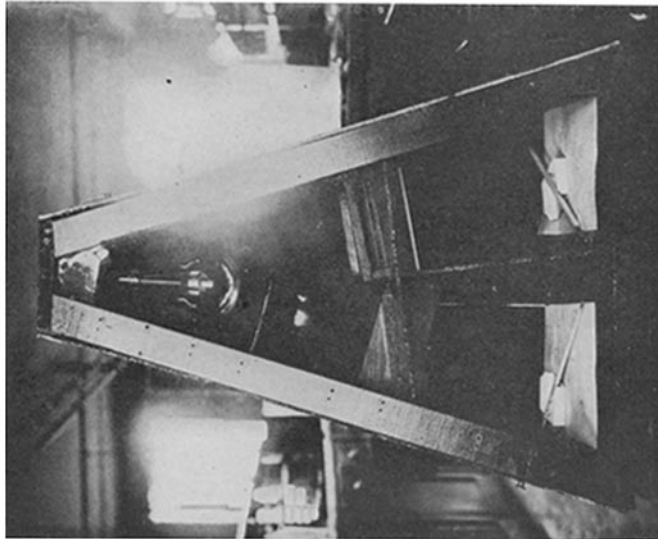
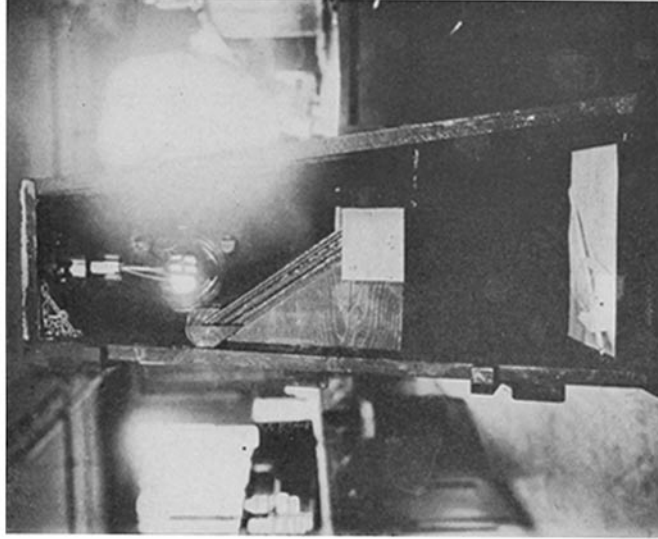


FIG. 2.

FIG. 1.

FIG. 1. Polarizing apparatus. Front view with door removed.
FIG. 2. Polarizing apparatus. Side view. Right wall removed and showing the chamber illuminated with polarized light.

before the comparison was made. Thus while the eye was used in comparing, it could not be argued that there might be a difference in the physiological effects of polarized and non-polarized lights on the eye. Of course such an objection would be purely hypothetical, as, so far as is known, no difference in the effects on the eye between polarized and non-polarized lights has ever been noted, and if such a difference should be experimentally demonstrated, it would be a fundamental physiological discovery.

In order to make sure that small variations in intensity of the control did not affect the results, a number of experiments were made with the non-polarized light of a slightly greater or slightly lesser intensity than the polarized light (by changing the number of plates in the control chamber). Such variations did not appreciably change the marked effect of the polarized light.¹

The temperatures in the two chambers were the same to within a fraction of a degree, as indicated by thermometer readings and also by thermographic tracings. Here again a number of experiments were made, in which the temperature in the control chamber was purposely made a little higher or a little lower than in the polarized chamber, respectively, and the results obtained still showed a definite stimulation of growth produced evidently by polarized light.

RESULTS.

Two sets of *Lupinus* seedlings, A and B, generally of 10 each, were carefully measured, then placed in hard glass tubes with Shive's solution, and one set was put in each chamber, Set A in polarized light, and Set B in non-polarized light. The plants were irradiated by the polarized and non-polarized lights, during the daytime, and were left in the dark overnight, when the electric current in the laboratory was turned off. On measuring the growth of the roots of the two sets of plants on the following day it was found that the seedlings exposed to polarized light had grown distinctly more than the other set. The two sets of plants were then interchanged, by placing them in the opposite chambers, that is Set B in polarized light and Set A in non-

¹In other experiments with polarized light, to be published later, intensities were compared by means of a bolometer.

polarized light, and exposed to the two kinds of light again. On the following day, when the growth of the roots was again measured, it was found that the original "non-polarized" set (B) which was this time exposed to polarized light actually outgrew the original "polarized" set (A) of plants, which, on this second day, was placed in the non-polarizing chamber.

The two sets of plants were again reversed for a second time, and it was found again that the seedlings grew more in polarized light. On reversing the position of the two sets a third time, better growth in polarized light was again observed. Such experiments with *Lupinus* seedlings were made a number of times with the same results. The following protocols will serve as illustrations.

TABLE I.

Set A.					Set B.				
Seedling No.	Normal length.	Polarized light.	Non-polarized light.	Polarized light.	Seedling No.	Normal length.	Non-polarized light.	Polarized light.	Non-polarized light.
	mm.	mm.	mm.	mm.		mm.	mm.	mm.	mm.
1	38	49	60	88	1	37	46	57	68
2	35	46	53	80	2	31	50	69	80
3	31	53	60	82	3	23	46	57	64
4	33	39	48	65	4	31	47	62	70
5	24	49	56	71	5	27	43	62	70
6	24	60	64	70	6	34	52	59	64
7	25	50	62	71	7	27	44	70	75
8	29	51	56	64	8	33	47	48	78
9	34	44	56	77	9	33	50	68	77
10	27	41	49	72	10	30	37	65	69
	300	482	564	740		306	462	617	715
		Increase 182.	Increase 82.	Increase 176.			Increase 156.	Increase 155.	Increase 98.

Table I gives the results of an experiment made on 2 sets of plants of 10 seedlings each. Set A was exposed to polarized light on the 1st day, to non-polarized light on the 2nd day, and to polarized light again on the 3rd day. In the case of Set B the order of exposure was

reversed, that is on the 1st day the plants were exposed to non-polarized light, on the 2nd day to polarized light, and on the 3rd day again to non-polarized light. The normal or original length of each root is indicated in the first column and the length at the end of each 24 hours in the successive columns. It will be seen that the increment in every case was greater when the seedlings were exposed to polarized

TABLE II.*

No.	Set A.					No.	Set B.				
	Apr. 26. Original length.	Apr. 27. Polarized.	Apr. 28. Non- polarized.	Apr. 29. Polarized.	Apr. 30. Non- polarized.		Apr. 26. Original length.	Apr. 27. Non- polarized.	Apr. 28. Polarized.	Apr. 29. Non- polarized.	Apr. 30. Polarized.
	mm.	mm.	mm.	mm.	mm.		mm.	mm.	mm.	mm.	mm.
1	47	55	69	81	76	1	33	57	70	82	72
2	42	60	78	74	79	2	32	58	61	68	82
3	47	53	65	87	70	3	36	51	68	70	70
4	38	66	69	71	75	4	45	53	75	78	71
5	48	50	62	76	80	5	42	68	74	79	77
6	32	64	64	77	76	6	40	57	71	81	74
7	39	52	65	77	70	7	45	56	71	72	64
8	45	67	62	77	85	8	36	64	71	76	76
9	37	48	69	80	71	9	49	53	64	69	80
10	35	54	68	68	72	10	42	62	76	73	75
11	36	68	66	72	72	11	48	49	61	77	78
12	42	59	68	73	70	12	44	47	60	78	81
13	37	59	74	74	72	13	33	61	73	77	79
14	51	63	63	77	75	14	48	60	69	75	72
15	42	56	58	73	69	15	45	57	63	75	85
	618	874	1000	1237	1112		618	852	1027	1130	1136
		Incre- ment 256.	Incre- ment 382.	Incre- ment 619.	Incre- ment 494.		Incre- ment 234.	Incre- ment 409.	Incre- ment 512.	Incre- ment 518.	

* In a few cases measurement of seedlings shows a shrinkage on the last day.

light and more than that, when the two sets of seedlings were reversed in respect to the form of radiation, the same phenomenon was noted, namely, the greater growth in polarized light.

In the experiments summarized in Table II two other sets of plants consisting of 15 seedlings each were treated as above, only in this experiment the interchange from polarized to non-polarized light and

TABLE III.
Experiment 10.

Series A ¹ .			Series B ¹ .		
May 3, 1926.	May 4, 1926.	May 5, 1926.	May 3, 1926.	May 4, 1926.	May 5, 1926.
Normal.	Polarized.	Non-polarized.	Normal.	Non-polarized.	Polarized.
50.1 mm.	67.3 mm.	75.4 mm.	51.9 mm.	64.6 mm.	77.4 mm.
Mean temp. 26°C.	Mean temp. 26°C.	Mean temp. 26°C.	Mean temp. 26°C.	Mean temp. 26°C.	Mean temp. 26°C.

TABLE IV.
Experiment 11.

Series A ² . (Covered seeds.)			Series B ² . (Covered seeds.)		
May 3, 1926.	May 4, 1926.	May 5, 1926.	May 3, 1926.	May 4, 1926.	May 5, 1926.
Normal.	Polarized.	Polarized.	Normal.	Non-polarized.	Non-polarized.
30.0 mm.	35.7 mm.	39.1 mm.	29.6 mm.	35.3 mm.	37.8 mm.
Mean temp. 22°C.	Seeds covered. Mean temp. 22°C.	Seeds uncovered. Mean temp. 22°C.	Mean temp. 22°C.	Seeds covered. Mean temp. 22°C.	Seeds uncovered. Mean temp. 22°C.

TABLE V.
Experiment 12.

Series A ³ . (Covered roots.)			Series B ³ . (Covered roots.)		
May 3, 1926.	May 4, 1926.	May 5, 1926.	May 3, 1926.	May 4, 1926.	May 5, 1926.
Normal.	Polarized.	Non-polarized.	Normal.	Non-polarized.	Polarized.
27.2 mm.	36.4 mm.	40.0 mm.	26.4 mm.	34.2 mm.	41.3 mm.
Mean temp. 22°C.	Mean temp. 22°C.	Mean temp. 22°C.	Mean temp. 22°C.	Mean temp. 22°C.	Mean temp. 22°C.

vice versa was made on 4 successive days until the plants were too long to be measured conveniently. Here again it will be seen that in every case greater growth took place in polarized light. (In this table the order of the seedlings is not the same in each column as they were not placed in individual tubes but in flasks containing several seedlings each.)

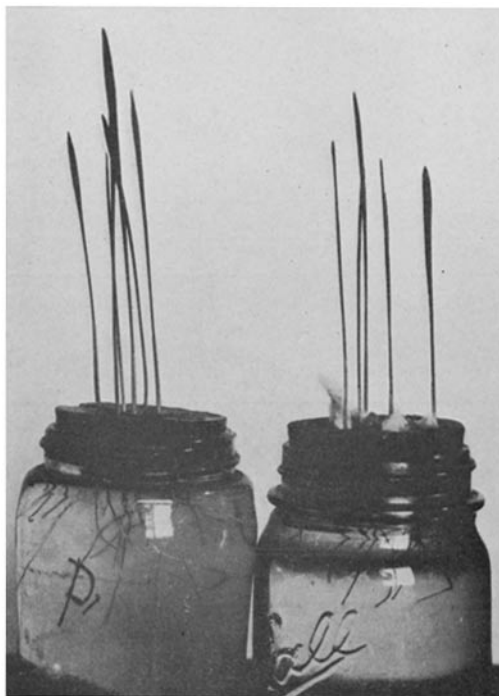
Table III shows an analysis of the above phenomena. In Experiment 10, two sets of plants consisting of 10 seedlings each were placed

TABLE VI.
Squash Seedlings.

Set A.				Set B.			
No.	Original length.	Polarized 24 hrs.	Polarized 72 hrs.	No.	Original length.	Non-polarized 24 hrs.	Non-polarized 72 hrs.
	<i>mm.</i>	<i>mm.</i>	<i>mm.</i>		<i>mm.</i>	<i>mm.</i>	<i>mm.</i>
1	47	58	69	1	45	55	57
2	36	47	54	2	34	37	47
3	32	44	58	3	32	34	47
4	21	27	46	4	22	25	31
5	41	51	71	5	43	54	45
6	31	40	63	6	33	44	80
7	42	47	56	7	37	40	83
8	21	29	52	8	22	35	63
9	19	28	66	9	21	26	34
10	16	26	55	10	18	30	38(?)
	306	397	590		307	380	525
		Increment 91.	Increment 284.			Increment 73.	Increment 218.

in polarized and non-polarized light, the figures here given indicating the sum of the root lengths. It will be noted here again that each set of plants grew better in polarized light. Experiment 11 illustrates the effect of wrapping the seeds or cotyledonous portion of the plants with tinfoil. It will be noted that when the beans were wrapped in tinfoil and thus protected from light altogether, growth was exactly the same in both chambers. When, however, these wrappings were removed on May 5th, better growth occurred in polarized light than in non-polarized light. Experiment 12 shows the results obtained

when the stems and roots of the seeds were protected from the light but the seed portion was left uncovered. Here better growth took place in polarized light than in non-polarized light thus indicating that the stimulation of growth by polarized light is due to photochemical changes induced in the seed portion. This, of course, harmonized prettily with the findings of Baly and Semmens and the



Polarized.

Non-polarized.

FIG. 3. Wheat seedlings.

present author in connection with the effect of polarized light on the diastatic hydrolysis of starch.

The author performed most of his experiments on seedlings of *Lupinus albus*. A number of experiments, however, were also performed on other plants. In Table VI are the results obtained with squash seedlings. Here again it will be noted that better growth

occurred in polarized light than in non-polarized light. A number of experiments were made with wheat seedlings; as these seedlings grow several roots which are difficult to measure, the growth was studied by measuring the elongation of the stems and leaves. In Table VII and Fig. 3 are shown the results obtained in one such experiment. Two sets of 6 seedlings each were exposed to polarized light and non-polarized light and the length from the root to the tip of the blade of

TABLE VII.
Wheat Seedlings.
(See Fig. 3.)

Set A.	Set B.
In polarized light.	In non-polarized light.
6 seedlings.	6 seedlings.
Original length from roots to tip of blade, 402 mm.	Original length from roots to tip of blade, 406 mm.
3 days later, 656 mm.	3 days later, 588 mm.
4 " " 921 "	4 " " 804 "

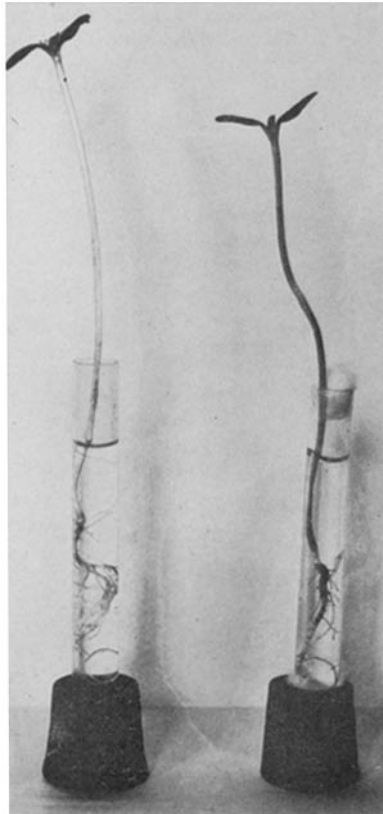
TABLE VIII.
Helianthus (Sunflower).
(See Fig. 4.)

Seedling A.	Seedling B.
Dec. 16, 1925. Length of stem, 120 mm. Placed in polarized light.	Dec. 16, 1925. Length of stem, 120 mm. Placed in non-polarized light.
Dec. 18, 1925. Length of stem, 140 mm.	Dec. 18, 1925. Length of stem, 125 mm.
" 19, " " " 147 "	" 19, " " " 127 "

each seedling was measured. It will be noted that better growth took place in polarized light. In several other experiments with wheat seedlings the growth of the plants was studied by weighing them. In this way it was also found that the seedlings exposed to polarized light weighed distinctly more than those exposed to non-polarized light. In Table VIII and Fig. 4 is shown the effect of polarized light on two seedlings of the sunflower, the length of the stems was measured and it will be noted better growth took place in the polarizing chamber.

SUMMARY.

While these experiments are not exhaustive, a sufficient number have been made to warrant the statement that the effect of polarized light of the visible spectrum on the growth of various seedlings and



Polarized. Non-polarized.

FIG. 4. Sunflower seedlings.

more particularly on the growth of *Lupinus albus* is somewhat different from that of non-polarized light. This is especially convincing in view of the results obtained with double sets of plants which were alternately exposed to polarized and non-polarized lights of the same

intensities and at the same temperature. In every experiment thus performed the set which was placed in a polarizing chamber grew better. It is, furthermore, interesting to note that the phenomenon above observed did not take place when the seed portion of the plants was protected from light by wrapping with tinfoil. This agrees well with previous findings concerning the action of diastase on starch in polarized light. The above researches will be continued on a more elaborate scale but the results so far obtained are deemed worthy of publication in the form of a preliminary communication at the present time.

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