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UNIVERSITY OF LOUISVILLE

THE EFFECT OF ULTRA-VIOLET LIGHT UPON
THE GROWTH OF ZEA MAIZE

A Dissertation

Submitted to the Faculty
Of the Graduate School of the University of Louisville
In Partial Fulfillment of the
Requirements for the Degree
Of Master of Arts

Department of Biology

By

W. H. Clashman

1930

23 Feb 30 EJB

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Dedication

In highest appreciation of the generosity
and kindness of Dr. Austin Ralph Middleton, whose
sympathetic direction contributed most to this work.

INTRODUCTION

Figure 1. Wave lengths in Angstrom units.

One Angstrom = $\frac{1}{10,000,000}$ of a millimeter in length.

Many experiments have been performed to determine the effect of ultra-violet light upon the growth of plants and animals. The conclusions reached by the experiments concerned are not constant in all cases.

The more significant of these studies are here reviewed. Sheard and Johnson (17) state that the skin is the medium which separates the organism, whether it be plant or animal, from its environment. The skin is, therefore, the medium of reception of radiant energy and the seat of transformation or utilization of the incident energy. No changes of a physical or chemical character are produced in the cells, tissues, or organisms unless there is an absorption of energy. Protoplasm exercises a pronounced absorption of energy of short wave lengths. Other researches have demonstrated that cytoplasm absorbs radiations of wave length 1600 Å and the nucleus absorbs radiations of wave length 1850 Å.

Rose (14) in an experiment in which he treated *Paramecium caudatum* with ultra-violet light, found that it was possible to modify the living system through light

radiations of wave lengths 1849Å to 3900 Å. Middleton (13) discovered that temperature produced heritable differences. Bosie and Hughes (2) discovered that ultra-violet radiation through a fluorite glass container caused cytolysis in paramecium when a certain amount of toxic substance is formed.

Bovie (3) called attention to the fact that all life ultimately depends on photosynthetic products formed through the agency of radiation from the sun, and a mathematical expression for the relation between exposure and effect is developed. Not only are carbohydrates formed in this manner, but also photo-chemical products essential to health. Rickets in children and other human ailments are compared to the etiolated condition obtained in plants deprived of light and evidence of a fundamental relationship is prevented.

McCrea (11) in an experiment with *Digitalis Purpurea* discovered that the plant develops a higher potency when subjected to the influence of ultra-violet light, also (12) that *Digitalis Purpurea* is benefited permanently by exposure during seedling development to irradiation by ultra-violet rays. Jacobs (8) states " Ultra-violet possesses a very

great formative effect on plants, causing the specific form of alpine flora".

Macht (9) points out that the effect of polarized light of the visible spectrum on the growth of various seedlings is somewhat different from that of non-polarized light. In every experiment performed the seedlings exposed to polarized light grew better. He states further that when the seed portion of the plants were protected with tin foil, the above phenomenon did not take place. Sheard and Higgins (15) draw the following conclusions from extensive experimentation:

1. Selective irradiation of the seed modifies the time of its germination and the rate of its subsequent growth.
2. The lesser wave lengths, in general, appear to stimulate, while the greater wave lengths inhibit growth.
3. Wave lengths ranging from about 3200 Å to 3900 Å seem particularly effective in inducing growth.
4. The stimulus to most rapid germination of seeds kept under interior diffuse daylight is an initial irradiation of from five to ten minutes. Longer periods of irradiation appear to have no stimulating

effect.

They (16) also state that the development of chlorophyll is enhanced under the yellowish green, green and greenish blue regions of the spectrum.

Ellis and Wells (5) grew plants in sunlight from which all wave lengths below 5290 Å were eliminated and obtained the following results:-

1. An increased rate of elongation of the main axis and usually a greater total length, with a reduction in the number of side-shoots or branches formed.
2. A considerable decrease in thickness of stem.
3. A general curling or rolling of leaves.
4. Good development of chlorophyll as indicated by appearance in comparison with controls in full sunlight.
5. Less compact and thinner walled cells, and a reduction in strengthening tissue.
6. Considerable delay in flowering and a reduction in the number of flowers produced.
7. Very weak fruiting and poor development of storage organs.
8. Decrease in fresh weight and dry weight and increase in percentage of moisture.

9. Considerable decrease in total carbohydrates and starch.

19. Decrease in some of the higher organic compounds and an increase in soluble nitrogen compounds.

THE SPECIFIC PROBLEM

Light has been recognized as one of the greatest economic factors of life. It is only recently, however, that its effects upon organisms have been studied scientifically. It was observed that organisms growing in darkness or diffused sunlight were different from those exposed to the direct rays of the sun.

These observations along with the contributions of science and invention led to further investigations and experimentations. One of these important discoveries was the ultra-violet ray.

The present study is an investigation of the effects of ultra-violet light of wave lengths 1849 Å to 3900 Å upon the growth of the seedlings of Zea Maize.

MATERIALS AND METHODS

In order that results obtained in experimentation designed to ascertain the effect of a single environmental factor upon the growth of plants, it is essential that the environment for both experimental and control groups be identical, except for the single factor under investigation.

For these experiments the following materials and methods were used. The vessels in which the seedlings grew during experimentation were glass dishes, nine inches in diameter and two inches in depth; the surface was regular and the glass was about two millimeters in thickness. Small quartz pebbles were placed in the dishes to support the paraffin beaver-board on which the grainsbearing the corn seedlings were placed. The paraffin beaverboards were perforated with holes one half inch apart. Through these holes the roots of the seedlings were planted. Each board contained twenty-five holes.

The glass vessels in which the seedlings were placed contained one-half inch of water. This amount was kept constant.

Four vessels were employed, - three experimental and one control. All were subjected to the same conditions except those under experimentation. The plants were subject to diffuse sunlight and room temperature.

The source of the ultra-violet rays was a Burdick-Cooper-Hewitt anode tungsten cathode quartz lamp, operated at seventy-five volts. The wave length of the rays transmitted ranged from 1849 Å to 3900 Å. The distance of the seedlings from the mercury arc was thirty inches.

The number of exposures varied with the experiments. Experiments number 1 and number 2 each had four exposures; experiments number 3, seven exposures; and experiments number 4, number 5, and number 6 each had eight exposures.

The length of irradiation period for each experimental group of seedlings remained constant throughout all experiments. The seedlings of group 1 of each experiment were subjected to three minutes exposure to the ultraviolet rays; those of group 2, to six minutes exposure; those of group 3, to ten minutes exposure.

Exposures were made daily at about 8 A. M. Only one group at a time was exposed. The remaining groups

were carefully protected from the ultra-violet rays.

No exposures were made until the lamp had attained a force of 75 volts.

The above procedure continued throughout each experiment. Accurate measurements of both the height and diameter were taken the day following the last irradiation. This data is in the accompanying charts.

EXPERIMENTS

Experimentation was conducted with corn seedlings (Zea Maize). The seed used for producing the sprouts was from selected ears fully matured in every way and of the same type. The grains from one ear were sufficient to supply sprouts for each experiment, thus assuring as nearly as possible uniformity of vitality and heredity.

Germination of the seed was under controlled conditions, at approximately 20 C. and about seventy-two hours were required for proper growth. Seedlings selected were as nearly the same size and vigor as could be picked from a large number. Probably from eight hundred to a thousand sprouts, one hundred were selected for the purpose of each experiment.

Experiment 1.

For this and each succeeding experiment, the sprouts selected were about five millimeters long and each had approximately a one inch root in length. The general condition of the plantlet was good.

As the seedlings were selected from the germinator they were immediately placed in position in the experimental

vessels. When the selection was completed, the vessels containing the seedlings were set aside for a period of twenty-four hours. This time was allowed for general adaptation of the sprouts.

Each dish of plantlets was numbered so that each group was easily distinguished, i. e., #1, #2, #3, and control. Each experimental dish was exposed to rays of wave lengths 1849 A to 3900 A at a distance of 30 inches from the mercury quartz arc. Plant group number 1 was exposed three minutes, number 2 six minutes, and number 3 ten minutes. Four exposures were made. On the day following the fourth exposure of the seedlings photographs of each group were taken, (Figs. 1, 2, 3, and 4) which show the development of the seedlings at this stage. The plants subjected to the ultra-violet rays were superior in size and vigor to the control and displayed a much greater leaf surface. The stems of the irradiated groups were also much greener and thicker.

Experiment 2.

January 4, 1930, a second experiment was started under the same conditions as experiment number one and for the same experimental period. The day following the

Figure 2. Control group average height 7 centimeters.

Figure 3. Experimental group number 3 -- 3 minute exposure

Figure 4. Experimental group number 3 - - 6 minute exposure

Figure 5. Experimental number 3. 10 minute exposure

Second Experiment - -4 Exposures

Plant	Ht. Cm.	Ht. Cm	Ht. Cm	Ht. Cm.
No.	Control	3 min.	6 min.	10 min.
<hr/>				
1	13.0	10.3	9.4	9.4
2	13.0	9.8	9.5	8.2
3	2.5	10.8	8.9	12.5
4		9.5	12.0	12.0
5		12.4	8.5	9.0
6.	9.2	8.1	11.3	5.0
7	4.0	7.6	10.2	11.5
8	4.2	8.1	8.2	13.5
9	2.0	9.7	8.5	7.0
10	5.0	8.2	8.7	12.2
11	11.5	2.5	9.0	8.5
12	4.0	6.5	9.0	12.5
13	4.0	5.5	10.1	10.0
14.	2.0	9.0	10.5	12.7
15.	5.0	6.4	9.6	10.5
16	12.0	9.4	7.3	11.0
17	7.5	12.4	2.0	10.2
18.	6.0	5.5	7.2	11.1
19		10.6	9.5	10.2
20	9.5	5.5	10.2	12.5
21	11.8	5.0	9.0	11.0
22	7.5	4.5	8.5	12.0
23	3.0	9.5	1.5	10.2
24	11.5	7.9	5.4	9.5
25	10.0	9.1	13.2	6.5
<hr/>				
Total	158.2	199.0	217.2	262.8
<hr/>				
Average	7.2	8.0	8.7	14.8
<hr/>				

Figure

FIG. 6.

fourth exposure to the ultra-violet rays, measurements of the seedlings were taken. In this experiment the height only was taken. The result is given in the following table.

In this experiment each group correspond closely to those of the preceeding experiment.

The control average height was 7.2 cm.; that of the group subjected to three minute exposure was 8. cm.; that of the group subjected to six minutes exposure was 9.cm.; and that of the group subjected to ten minutes exposure 14.cm.

Table shows the height attained by each individual seedling. Figure is a graph of the distribution of these seedlings as to the height.

EXPERIMENT 3.

Experiment number 3 was prepared and conducted in the same manner as number 2 except that the experimental groups were exposed to the ultra-violet light seven times instead of four. The experiment appeared quite comparable in every way to the preceeding experiment up to the fourth exposure. It was quite noticable from this stage on that the control stems lengthened more rapidly than the experimental. The stems of the control were more slender and

Third Experiment Seven Exposures

Plant	Control	Ht.Cm.	Ht.Cm.	Ht.Cm.	Dia.Mm.	Dia.Mm.	Dia.Mm.	Dia.Mm.
No.	Ht.Cm.	3 min.	6 min	10 min	Control	3 min	6 min	10 min
1	17.5	17.0	15.0	1.0	2.0	2.1	2.0	1.0
2	14.0	13.0	9.5	17.0	1.5	1.7	2.5	2.5
3	17.0	19.0	11.0	7.0	1.9	1.9	2.1	1.9
4	22.0	9.0	10.0	11.0	2.1	2.4	1.9	2.5
5	16.0	11.0	10.0	15.0	1.3	2.0	2.0	2.8
6	17.0	10.0	10.0	19.0	2.2	1.8	2.0	2.5
7	1.0	18.0	14.5	15.0	1.0	2.3	2.5	2.3
8	17.0	16.0	10.5	17.0	1.7	2.4	2.1	2.8
9	18.0	17.0	11.0	14.5	1.9	2.0	2.1	2.6
10	15.0	16.0	8.0	13.5	2.0	2.0	2.0	2.1
11	11.0	18.0	18.0	18.0	1.5	2.1	2.7	2.4
12	14.0	11.0	10.0	16.0	1.9	1.8	1.5	2.3
13	9.0	13.0	11.0	15.5	1.4	1.8	2.3	2.1
14	7.0	10.0	17.0	19.0	1.1	2.4	1.7	2.4
15	13.0	10.0	10.5	13.0	2.1	2.5	1.8	1.7
16	18.0	15.0	16.0	12.0	2.2	2.3	2.5	1.9
17	16.0	16.0	15.0	18.0	1.9	1.7	2.4	2.6
18	13.0	10.0	13.5	15.0	1.7	2.1	2.0	2.1
19	19.0	12.0	11.0	17.0	2.1	2.0	2.0	2.2
20	15.0	15.0	13.5	14.0	2.3	2.5	2.5	2.8
21	21.0	17.0	13.0	18.0	1.8	2.0	2.7	2.7
22	6.0	13.0	10.0	14.0	1.0	2.1	2.3	2.5
23	18.0	14.0	15.0	18.0	2.0	1.7	2.8	2.0
24	17.0	11.0	11.0	17.0	2.0	1.5	1.5	2.4
25	19.0	17.0	11.5	18.0	1.9	2.0	1.7	2.5
Total	370.5	348.0	305.0	372.5	45.0	50.0	52.8	57.6
Average	14.8	13.9	12.2	14.9	1.8	2.0	2.1	2.3

Figure 6

FIG. 7.

EXP. N0.3

weak. In many instances they were unable to stand erect. Dane (14) found the stems of the irradiated plants were approximately one and one-half times as large in diameter as the control plants.

Experiment 4.

The materials and methods were the same as for previous experiments except that eight exposures were given. We found it impractical to give a greater number of irradiations since accurate data was not easily obtained from older and longer seedlings. The stems of the control became bent and twisted and indeed the seedlings of all groups inclined to fall since there were no holdfasts for the roots, probably due to the increase in weight of the aerial portion of the plants. General comparison was more easily made at this or earlier stages of development.

We found as a result of the experiment that the irradiated plants continued to show much more vigor, more especially in the ten minute exposure. The leaf surface was greater; the internodes were shorter and thicker and the entire plant above the first node gave a thrifty green appearance as though it had been cultivated under normal summer conditions.

Fourth Experiment Eight Exposures

Plant Ht. Cm. Ht. Cm. Ht. Cm. Ht. Cm. Dia. Mm. Dia. Mm. Dia. Mm. Dia. Mm.

No. Cont. 3 min. 6 min. 10 min. Cont. 3 min. 6 min. 10 min

1	20	19.5	14.	14.	2.1	2.2	2.1	2.5
2	15.2	13.5	14.	21.	1.9	1.9	2.6	2.8
3	22.	19.5	14.6	15.	2.3	2.0	2.2	2.8
4	23.5	9.7	15.	18.	2.5	2.3	2.1	2.3
5	26.7	12.5	15.	16.	2.4	2.3	2.3	3.0
6	13.	18.3	15.	17.5	1.1	1.7	2.7	3.0
7	24.5	20.5	16.5	17.	2.0	2.5	2.5	2.1
8	21.5	20.5	16.	18.5	1.6	2.6	2.9	2.0
9	8.	12.	17.	19.	1.2	2.1	1.7	3.0
10	22.5	14.5	10.	16.5	2.0	2.5	1.8	2.5
11	17.5	17.	15.2	16.5	2.0	2.4	2.1	2.7
12	12.	13.	16.	21.	1.5	2.2	2.5	2.4
13	25.	13.	15.5	20.	2.1	1.9	2.1	2.2
14	20.5	9.	16.2	15.	2.3	2.0	2.1	2.3
15	23.	15.	13.	14.	2.2	2.6	2.0	2.5
16	25.2	18.	16.5	20.	2.2	2.7	2.3	2.6
17	21.	18.	17.0	21.5	1.6	2.4	2.5	2.2
18	7.	22.	15.	18.	1.7	1.9	2.0	3.1
19	23.	21.	16.5	13.5	2.	2.5	2.7	2.0
20	15.	16.4	17.5	17.	2.0	2.7	2.5	2.2
21	21.7	24.	17.5	17.	2.0	2.7	2.5	2.2
22		22.	13.	17.5		2.0	2.3	2.9
23	20.	13.5	15.	20.	1.8	2.2	2.8	2.1
24	19.	26.0	14.3	13.5	2.0	2.1	2.7	2.7
25	3.	18.	11.	7.	1.3	1.9	2.0	2.0

Total 435.1 431.4 381.8 423.2 44.8 55.7 57.8 63.9

Average 18,13 17.256 15.272 17.128 1.362 2.28 2.312 2.556

Figure 8.

Fig. 9

EXP. NO. 4

In table 3, measurements are given for the different groups. As shown by this table, the controls attained the greatest average height, 1, e., 18.13 cm.; the three minute exposure, second, 1. e., 17.25. cm.; the ten minute exposure, third, 1.e., 17.12 cm.; and the six minute exposure was fourth, 1.e., 15.27 cm.

The diameters of the groups were as follows:

Average diameter of control -----	1.862 mm.
Average diameter of three minute exposure -----	2.28 mm.
Average diameter of six minute exposure -----	2.312 mm.
Average diameter of ten minute exposure -----	2.556 mm..

All measurements of diameter were taken just above the first node.

Experiments 5 and 6.

Experiments five and six were under the same conditions as experiment number four and exposures to ultra-violet rays were of the same duration.

The results of these experiments were very similar in every way to the preceeding one. The measurements in height and diameter averaged very closely to the above figure.

Another characteristic which was common to the ten minute exposure was a purplish color of the stem. This was more prominent in some experiments than others. The

Fifth Experiment Eight Exposures

Plant Control 3 min. 6 min. 10 min Control 3 min. 6 min. 10 min

No. Ht. Cm. Ht. Cm Ht. Cm Ht. Cm Dia. Mm Dia. Mm Dia. Mm. Dia. Mm

1	16.8	19.2	13.0	20.0	1.8	2.2	2.5	3.0
2	19.0	28.5	15.0	20.0	2.5	2.0	2.1	3.0
3	23.0	18.0	15.6	14.0	2.7	2.0	2.2	2.1
4	21.0	21.0	14.0	15.2	2.0	2.7	2.1	2.1
5	23.0	25.5	14.5	15.0	2.4	2.4	2.6	2.3
6	15.0	16.4	15.4	17.0	2.2	2.0	2.7	2.8
7	16.5	21.5	16.0	17.0	2.0	2.4	2.6	3.0
8	18.0	21.5	16.0	18.5	1.7	2.7	2.6	2.3
9	19.0	18.0	17.5	17.0	1.8	2.5	2.0	2.5
10	21.0	18.5	8.0	13.0	2.0	2.7	2.0	2.8
11	16.5	19.5	17.2	15.0	2.3	2.0	2.1	3.0
12	24.5	4.0	16.2	16.5	1.7	1.6	2.0	2.0
13		13.0	16.0	15.5		2.4	2.0	2.2
14	15.0	12.0	15.5	21.0	1.8	2.0	2.3	3.0
15	17.5	13.0	16.0	16.5	2.0	2.5	2.2	2.0
16	15.2	18.5	13.5	16.5	1.6	2.0	2.1	2.6
17	17.5	8.0		20.0	1.9	2.6		2.2
18	21.0	20.5		22.0	2.1	2.7		2.4
19	12.0	12.5	15.0	19.0	2.0	2.0	2.5	2.3
20	20.5	13.3	12.0	21.0	1.5	2.5	2.6	2.4
21	21.0	20.5	16.5	20.5	1.1	2.5	2.6	2.4
22	25.0	0.7	17.0	13.0	2.3	1.7	2.5	2.7
23	17.3	19.5	13.0	13.5	1.8	2.6	2.5	2.3
24	15.5	13.5	14.5	20.0	2.0	2.0	2.0	3.1
25	9.0	19.5		17.5	1.7	2.5	2.1	2.7

Total	439.8	435.1	319.5	439.2	46.9	57.2	52.8	63.3
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Average	18.32	17.4	14.52	17.56	1.95	2.28	2.29	2.53
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Figure 10

FIG. 11

EXP. NO. 5

Sixth Experiment

Eight Exposures

Plant	Ht. Cm.	Ht. Cm.	Ht. Cm.	Ht. Cm.	Dia. Mm	Dia. Mm	Dia. Mm	Dia. Mm
No.	Control	3 min.	6 min.	10 min.	Control	3 min.	6 min	10 min
1	28.5	16.8	12.0	21.0	2.5	2.4	2.0	2.9
2	19.2	19.0	16.0	19.0	1.8	1.6	2.6	2.1
3	22.0	23.0	15.6	14.0	2.4	2.6	2.2	3.0
4	17.0	21.0	14.0	15.2	2.4	2.1	2.1	2.2
5	25.5	23.0	13.5	15.0	2.7	2.7	2.4	2.2
6	16.4	16.5	16.5	18.0	2.2	2.5	2.9	3.0
7	19.5	15.0	16.0	18.5	1.6	1.9	2.5	2.8
8	13.5	20.0	17.0	16.0	2.0	2.4	2.7	2.3
9	19.5	29.0	16.5	20.0	2.0	2.7	2.0	2.8
10	9.7	18.0	6.0	15.0	2.3	2.0	1.5	2.5
11	20.5		17.2		2.1		2.6	
12	13.3	16.5	16.2	16.5	1.7	2.0	2.0	2.0
13	12.5	24.5	16.0	21.0	1.5	2.5	2.0	3.0
14	20.5	14.0	15.5	15.5	2.0	2.0	2.1	2.2
15	8.0	18.5		15.5	2.0	2.6		2.0
16	18.5	15.2	15.5	19.5	1.6	2.7	2.3	2.6
17	18.0	17.5		23.0	2.0	2.0		2.3
18	12.0	22.0	16.0	19.0	1.2	2.5	2.5	2.3
19	13.0	11.0	15.0	20.0	2.0	1.7	2.3	2.2
20	4.0	20.5	19.0	20.0	1.1	2.5	2.5	2.5
21	19.5	25.0	16.5	13.0	2.4	2.2	2.7	2.3
22	18.5	21.0		13.5	2.5	2.4		2.3
23	18.0	17.3	16.0	20.5	2.3	1.9	2.3	2.6
24	21.5	14.5	19.0	17.5	1.9	2.0	2.7	2.6
25	21.5	9.0	14.5	20.0	2.1	2.2	2.0	3.1
Total	435.1	438.8	317.5	424.2	50.3	54.1	51.4	59.9
Average	17.4	18.2	14.0	17.5	2.0	2.27	2.35	2.59

Figure 12

FIG. 13.

plants, however, did not seem less vigorous because of this factor.

Tables four and five give the measurements for these experiments, and the accompanying graphs show the curves for the heights of the various groups.

SUMMARY AND CONCLUSION

Sheard, Higgins, and Foster (16) find the average height of stalks to be greatest in the infra-red and red red regions at the one extremity of the solar spectrum and in the violet and ultra-violet portions at the other extremity of the spectrum, and least under green and heat absorbing filters. Dane (4) finds that the diameter of plants are increased by exposure to ultra-violet rays.

Experiments number one and two show that the experimental groups were longer and thriftier than the control. The general appearance of the irradiated groups was normal, while the control gave the characteristic appearance of seedlings grown in diffused light.

In summarizing the general measurements and averages for all experiments under investigation, we find that;

In experiment number one the irradiated groups were stimulated to an earlier growth and that the plants were larger and more vigorous throughout the experimental period.

In experiment number two, similar results of the corresponding groups of experiment number one were obtained.

The irradiated seedlings gave the appearance of a normal environment while those of the control group were spindling and lacked chlorophyll. The average height of the seedlings of the control group was 7.2 centimeters; that of the twenty-five seedlings given ultra-violet radiations for three minutes daily during four consecutive days was 8.0 centimeters; that of the twenty-five seedlings given ultra-violet radiations for six minutes daily during four consecutive days was 8.7 centimeters; and that of the twenty-five seedlings irradiated for ten minutes daily during four consecutive days was 14.8 centimeters.

The average height of the various groups of experiment number two were:

The control group of seedlings averaged 7.2 centimeters in height. The seedlings that were exposed three minutes averaged 8.0 centimeters in height. Those for the six minute exposure averaged 8.7 centimeters in height, and those of the ten minute irradiation 14.8 centimeters in height.

In experiment three, seven exposures were given the experimental groups. The control of twenty-five seedlings had an average height of 14.82 centimeters and an average

diameter of 1.8 millimeters. The twenty-five seedlings of the group given ultra-violet radiations measured 13.92 centimeters in height and 2.0 millimeters in diameter. The twenty-five seedlings of the group given six minutes exposure measured 12.22 centimeters in height and 2.112 millimeters in diameter, and the twenty-five seedlings of the group given ten minute exposures measured 14.9 centimeters in height and 2.304 millimeters in diameter. In this experiment the control seedlings grew more rapidly in height than the exposed seedlings during the latter part of the experimental period. The weak condition of the control continued in this experiment and the plants were unable to stand erect. In experiments numbers four, five, and six the experimental groups were given daily exposures of the same duration as in the corresponding groups of the preceeding experiments, but they were given eight exposures instead of four or seven as in the earlier experiments. In experiment number three, in which the experimental seedlings were exposed for seven consecutive days, the exposed seedlings underwent the same rate of development during the first four days of exposure as the corresponding groups of experiments

numbers one and two, but during the last three days of exposure they increased more rapidly in diameter and did not elongate so rapidly as the control group. In experiments number four, number five, and number six this same phenomenon was observed, i.e., the experimental seedlings underwent, during the first four days of exposure, a development paralleling that of the corresponding seedlings of experiments number one and number two, and during the fifth, sixth, and seventh days they underwent a development paralleling that of the corresponding seedlings during the corresponding days of experiment number three. During the eighth day of their exposure they continued to manifest the same developmental tendencies as those shown by them and by the experimental seedlings of experiment number three during the days of exposure subsequent to the fourth. In other words, they elongated less rapidly than the control seedlings and increased more rapidly than the control seedlings in diameter.

The control seedlings of experiment four averaged 18.13 centimeters in height and 1.862 millimeters in diameter. The group exposed three minutes daily averaged 17.256 centimeters in height and 2.28 millimeters in diameter. The group exposed six minutes daily measured 15.272 centi-

meters in height and 2.312 millimeters in diameter, and the group exposed ten minutes daily averaged 17.128 centimeters in height and 2.556 millimeters in diameter. The plants of the group exposed ten minutes daily displayed a purplish color along the stem which had not been evidenced in previous experiments. The seedlings however, seemed quite as vigorous as normal seedlings. The plants were stalky, the internodes short and thick. The supporting tissue was abundant and turgescence was good.

Experiment number five. In this experiment the average measurements were for the control group 18.325 centimeters in height and 1.95 millimeters in diameter; for the three minute exposed group 17.4 centimeters in height and 2.28 millimeters in diameter; for the six minute exposed group 14.52 centimeters in height and 2.29 millimeters in diameter; and for the ten minute exposed group 17.568 centimeters in height and 2.532 millimeters in diameter. This last group of seedlings gave every evidence of normal thrifty development as in the corresponding group of experiment four, and again the purplish color of the stems was present. The root system of the various groups seemed to correspond with the aerial portions in length and diameter.

Experiment number six gave the same characteristics developed in experiments number four and number five. The

average measurements were: for the control group 17.4 centimeters in height and 2.0 millimeters in diameter; for the three minute exposed group 18.2 centimeters in height and 2.27 millimeters in diameter; for the group exposed six minutes 14 centimeters in height and 2.35 millimeters in diameter; and for the group of seedlings exposed ten minutes 17.5 centimeters in height and 2.50 millimeters in diameter.

A general average of the measurements was computed for experiments number five and number six and were found to be as follows: the control group of seedlings averaged 17.952 centimeters in height and 1.937 millimeters in diameter. The group of seedlings irradiated three minutes measured 17.608 centimeters in height and 2.27 millimeters in diameter. The seedlings which had been exposed to the ultra-violet light for six minutes measured 14.597 centimeters in height and 2.317 millimeters in diameter; and those groups of seedlings which had been irradiated for ten minutes daily, measured 17.398 centimeters in height and 2.527 millimeters in diameter. The average measurements for the individual experiments and the general averages are contrasted in table below.

In the various groups of all experiments we observed that the seedlings which were exposed ten minutes daily were

- - - - -Average height - - - 4 - - - -Average diameter - - -								

	Cont.	3 min.	6 min.	10 min.	Cont.	3 min.	6 min.	10 min.

Exp. 4	18.130	17.256	15.272	17.128	1.862	2.28	2.312	2.556
Exp. 5	18.325	17.400	14.520	17.568	1.950	2.28	2.290	2.532
Exp. 6	17.400	18.200	14.000	17.500	2.000	2.27	2.350	2.500

Gen. Av.	17.952	17.608	14.597	17.398	1.937	2.27	2.317	2.527

Table

quite superior to any of the other groups. The plants were more nearly uniform in size and quality. This regularity of height made the average for this group about equal to that of the control regardless of the fact that the control seedlings inclined to develop long and slender stems.

The seedlings irradiated six minutes were shorter than the other groups but were very normal in appearance. The seedlings had a good leaf surface and thrifty color and stem.

The seedlings exposed three minutes daily to the ultra-violet were not so thrifty in appearance as the plants which were subjected to longer exposures. The seedlings appeared more spindling. The stems were not so green as those of the six or ten minute groups, and the seedlings seemed to lack supporting tissue. However it was easily observed that they

were superior to the control group of seedlings. They really seemed to form a half way mark between the control seedlings and the group of plants which were exposed ten minutes. In some of the experiments we took the wet and dry weights of the different groups. Generally the weights were proportionaal to the measurements of the plants. There seemed to be a slight deviation from this in the experimental groups. The experimental seedlings seemed to lose a higher percentage of moisture from the wet to the dry weight, than the seedlings of the control group.

As far as the seedlings of these experiments are concerned the following results were manifest:

1. Seedlings of Zea maize grown in diffuse daylight are a lighter green than those that develop in direct sunlight.
2. These seedlings also elongate more than those grown in sunlight and their stems lack supporting tissues.
3. Seedlings from the same ear, when exposed daily for four consecutive days, at thirty inches from the mercury arc of a Burdick-Cooper-Hewitt lamp, to ultra-violet radiations of from 1849 Å to 3900 Å averaged greater in length, were a darker green and did not lack supporting tissues.
4. Seedlings from the same ear, when exposed daily for seven or eight consecutive days, at thirty inches from

a Burdick-Cooper-Hewitt mercury arc lamp, to ultra-violet radiations of from 1849 Å to 3900 Å averaged shorter in length, were a darker green than the control group and those exposed for shorter periods daily had a purplish cast and developed measurably sturdier stems.

5. In wet weight the experimental groups uniformly averaged heavier than the corresponding groups.

6. When dried, the experimental groups lost more in weight than the corresponding control groups.

7. The development of root systems corresponded closely in weight with that of the shoot in all the groups, experimental and control.

8. Since the seedlings were all grown in tap water culture, the measurably greater weight of the experimental seedlings was probably due to a more rapid absorption of the endosperm of the seed, and since the experimental seedlings lost more weight through drying than did their controls, their greater weight was probably due to a greater retention of water by their tissues.

9. Ultra-violet light of from 1849 Å to 3900 Å has functioned as a substitute for direct sunlight in causing a more "normal" development of the experimental seedlings of these experiments than was shown by their controls grown in diffuse daylight. It is, therefore,

probable that it is these solar radiations that are principally responsible for the usual development of seedlings.

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