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Studies In Breaking The Rest Period of Grass Plants By Treatments With Potassium Thiocyante and In Stimulating Growth With Artificial Light

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STUDIES IN BREAKING THE REST PERIOD OF GRASS PLANTS BY TREATMENTS WITH POTASSIUM THIOCYANATE AND IN STIMULATING GROWTH WITH ARTIFICIAL LIGHT

being

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by

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A C K N O W L E D G M E N T

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CONTENTS

	Page
INTRODUCTION	1
RELATED STUDIES	2
MATERIALS AND METHODS	4
Obtaining the Sods	4
Care of Plants Before Treatment	4
Treatment	5
RESULTS OF TREATMENT	8
Short Grasses	8
Blue Grama Grass	8
Buffalo Grass	12
Tall Grasses	15
Tall Grama Grass	15
Western Wheat Grass	18
Big Bluestem Grass	23
General Results	25
SUMMARY	27
REFERENCES CITED	29

LIST OF ILLUSTRATIONS AND TABLES

Fig. Page

1. Photograph of equipment 6
2. Blue grama grass, short-day series, showing killing effect of 2.0 per cent and 1.0 per cent solutions 11
3. Blue grama grass, short-day and long-day series 12
4. Tall grama grass, long-day series, showing erratic response to chemical treatment . . . 17
5. Tall grama grass, short-day and long-day series, showing stimulating effect of chemical and supplemental light 18
6. Western wheat grass, long-day series, showing killing effect of 2.0 and 1.0 per cent solutions 19
7. Western wheat grass, short-day series, showing killing effect of 2.0 and 1.0 per cent solutions 20
8. Western wheat grass, short-day and long-day series, showing stimulating effect of chemical and supplemental light 22

Fig. Page

9. Western wheat grass, long-day series, contrasting the effect of chemical and freezing upon growth 22

Table

I. Effect of potassium thiocyanate, supplemental light and out-door freezing upon blue grama grass 10

II. Effect of potassium thiocyanate, supplemental light and out-door freezing upon buffalo grass 14

III. Effect of potassium thiocyanate, supplemental light and out-door freezing upon tall grama grass 16

IV. Effect of potassium thiocyanate, supplemental light and out-door freezing upon western wheat grass 21

V. Effect of potassium thiocyanate, supplemental light and out-door freezing upon big bluestem grass 24

I N T R O D U C T I O N

For several years there has been much interest in ecological pasture studies. This has necessarily placed emphasis upon the study of grasses, especially of their vegetative characters, since it is by these characters that closely-grazed grasses must be identified. The attempt of the government to control the dust storms in the Great Plains region by revegetation has aroused added interest in grass studies. This practical interest in grasses and the accompanying demand for men well trained in grass identification has made it desirable that college and university botany and agriculture classes study grasses in the fall and winter months. Since many grasses in the Great Plains region become dormant, dry, and sere in the fall and remain in this condition until spring it has been necessary to bring sods into the greenhouse and grow them for study. This has not proved very successful since many grasses remain dormant for the greater part of the winter and will not grow even though given an artificial climate with optimums of temperature and light duration. If sods of grasses are given an optimum artificial climate after their rest periods have been broken

by freezing weather they will produce enough vegetative growth for study. However, in exceptionally cold winters, if the ground has been frozen solidly it is often impossible to take up the sods even though they would grow if placed in the greenhouse. Consequently, it has usually been late in the year before the vegetative characteristics of grasses could be satisfactorily studied.

There has developed a need for a practical means of artificially breaking the rest period and of stimulating the growth of grasses so that sods can be procured early in the fall before freezing weather, brought into the greenhouse, and forced early to make an abundant vegetative growth. This need suggested the study of which this paper is the report, namely to discover whether or not the rest period of native grasses can be broken by treatment with potassium thiocyanate and their growth stimulated by artificial light supplemental to winter daylight.

RELATED STUDIES

Perhaps the most successful work on rest-period breaking is that done on potatoes and gladiolus by Denny and Miller. They have been successful in hastening the sprouting of dormant potato tubers by treatments with either

potassium thiocyanate, sodium thiocyanate, ethylene dichloride, ethyl bromide, carbon bisulphide, trichloroethylene, ammonium thiocyanate, or ethyl iodide (1,2,3). Denny working with Miller (4,5) has also broken the rest period of gladiolus cormels by treatment with ethylene chlorhydrin and by storage at low temperatures. Stanton and Denny (6) were successful in forcing some dormant woody plants with chemical vapors.

It has long been an established fact that growth and period of flowering of plants can be controlled by regulating the duration and intensity of the light they receive. Chief among the contemporary workers in photoperiodism are Garner and Allard of the United States Department of Agriculture. Garner (7) compared the responses of long-day and short-day plants to the relative length of day and night, and with Allard (8) he localized the response in plants to relative length of day and night. The same men (9) studied the duration of the flowerless condition of plants in response to unfavorable lengths of day.

Although experiments have been performed in the attempt to break the rest period of other plants by treatment with chemicals and to stimulate growth and hasten flowering of plants by regulation of light intensity and duration, little or no work of this nature has been done with grasses. Some

photoperiodic experiments have been conducted on grasses by Weaver and Himmel (10), Emerson (11), and Evans (12). To the author's knowledge, however, no attempt has been made to break the rest period of grasses by chemical treatment.

MATERIALS AND METHODS

OBTAINING THE SODS

On October 13, 1937, sods of the following five kinds of grasses were cut to fit and were placed in 6-inch pots: blue grama grass (Bouteloua gracilis), buffalo grass (Buchloe dactyloides), tall grama grass (Bouteloua curtipendula), western wheat grass (Agropyron smithii), big bluestem grass (Andropogon furcatus). To save space, the sods for the pots were selected so that each contained grass plants of two different kinds. The grasses were potted together in the following combinations: buffalo grass with blue grama grass, tall grama grass with western wheat grass, and tall grama grass with big bluestem grass.

CARE OF PLANTS BEFORE TREATMENT

The potted grasses were brought into the greenhouse

and placed on a bench equipped with bottom heat. Here they were watered and their leaves were clipped to within about 1 inch of the surface of the soil.

To insure that the plants were in a state of dormancy, a period of 36 days was allowed to elapse between the time the plants were brought into the greenhouse and the time they were treated. During this interval the plants received water as needed, but were given no other treatment.

TREATMENT

On November 18, six sods of each kind of grass used in the experiment were treated with an aqueous solution of potassium thiocyanate (KSCN), of the following concentrations: 2.0 per cent, 1.0 per cent, 0.5 per cent, 0.1 per cent, 0.01 per cent and 0.001 per cent. The solution was applied by pouring 200 cc. about the crowns of the plants in each sod. This wet the soil in the pots to an average depth of 5 centimeters. Six sods of each kind of grass used in the experiment were left untreated as control plants.

After chemical treatment the sods were divided as to kind and number into two like series. One series is termed the "long-day" series; the other is designated the

"short-day" series.

Plants in the long-day series were arranged in such a manner that they received artificial light supplemental to daylight from 300W-230V Mazda bulbs in reflectors 3 feet apart (13) suspended 22 inches above the pots (Fig.1). The lights were turned on at sundown each day and turned off at 11:30 P.M., giving an average day-length of 16 hours for the duration of the experiment. Plants in this series are termed "long-day" plants.

Fig. 1. Photograph of Equipment. Long-day series under lights in foreground. Short-day series under shading-frame in background.

Plants in the short-day series were placed close to those in the long-day series and arranged under a frame in such a manner that they could be draped with a black sateen cloth which excluded nearly all light (Fig. 1). These plants were allowed to receive only light of the normal winter-day duration. Plants in this series are termed "short-day" plants.

On December 30, after considerable freezing weather, sods of the kinds of grasses used in the experiment were obtained from out-of-doors. These were potted in the same manner as were those that received chemical treatment.

With the exception that the long-day series received light supplemental to daylight, both series received the same treatment. The plants were watered often enough with a hose spray to keep the soil moist. The average daily room temperature for the duration of the experiment was 72° F.

Detailed records were kept for each sod, notations being made of the date of resumption of growth after treatment, average height, vigor, density, and per cent survival.

RESULTS OF TREATMENT

SHORT GRASSES

Blue Grama Grass

For the first two weeks before chemical treatment blue grama grass remained green and, in some cases, made slight growth. However, before the end of the 36-day period prior to treatment the plants were yellow and in a dormant condition.

Twenty-one days after treatment, green leaves had pushed up through the culms of both short-day and long-day plants treated with potassium thiocyanate of 0.1 per cent concentration (Table 1). In the short-day series plants treated with a solution of 0.001 per cent concentration also began growth 21 days after treatment. All concentrations of the solution except 2.0 per cent and 1.0 per cent initiated growth in plants so treated before growth began in the control plants. The control plants began growing 54 days after treatment, or 33 days after the beginning of active growth in the treated plants.

A 2.0 per cent solution killed all plants so treated in both series (Fig. 2). All long-day plants treated with a 1.0 per cent solution were killed, and while this concentration did not completely kill the short-day plants it

had a killing effect as judged by per cent survival and foliage appearance.

Table I. Effect of Potassium Thiocyanate, Supplemental Light and Out-door Freezing upon Blue Grama Grass.

Treatment	Effect of Treatment: Averages				
	No. of days after treatment until growth began	Average Height (cm) 95 days after treatment	Average Height (cm) 140 days after treatment	Per cent survival	No. of days after treatment until flowers appeared
Long-day Series					
Control	54	27	37	96	139
2.0 % KSCN	dead	dead	dead	dead	
1.0 % "	dead	dead	dead	dead	
0.5 % "	49	24	32	50	
0.1 % "	21	27	61	95	
0.01 % "	44	31	48	98	139
0.001 % "	44	29	52	98	139
Out-door Freezing	4*	29	61	98	139
Short-day Series					
Control	54	9	9	98	
2.0 % KSCN	dead	dead	dead	dead	
1.0 % "	54	10	10	10	
0.5 % "	49	12	12	50	86
0.1 % "	21	8	8	98	
0.01 % "	49	15	15	98	
0.001 % "	21	12	12	98	
Out-door Freezing	4*	10	10	98	

* Number of days after frozen plants were brought into the green-house on December 30 until growth began.

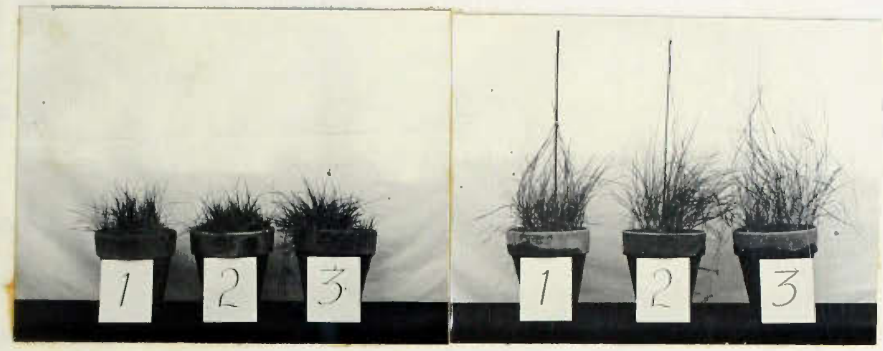
Fig. 2. Blue Grama Grass: short-day series. Shows killing effect of 2.0 per cent and 1.0 per cent solutions. Photograph taken 54 days after treatment. (1) Control, (2) 2.0 per cent, (3) 1.0 per cent, (4) 0.5 per cent, (5) 0.1 per cent, (6) 0.01 per cent, (7) 0.001 per cent, (8) Frozen.

Nearly all concentrations of the solution except 2.0 and 1.0 per cent stimulated plants to greater growth in height (Fig. 2).

Chemical treatment did not hasten flowering with one exception; this was a short-day plant treated with a 0.5 per cent concentration. It flowered 86 days after treatment; none of the short-day control plants flowered. Supplemental light induced flowering 139 days after treatment. Strong concentrations of the solution seemed to inhibit flowering. Frozen plants flowered at the same time as did the controls.

Plants which had been frozen began growth 4 days after having been brought inside on December 30; at the end of

the experiment they had made as much growth as the treated plants had made (Fig. 3).



Short-day Series Long-day Series

Fig. 3. Blue Grama Grass
Photograph taken 95 days after treatment. (1) Control, (2) 0.1 per cent, (3) Frozen.

Buffalo Grass

Buffalo grass remained green for about two weeks after it was brought into the greenhouse. Slight evidences of growth were observed in a few plants shortly after being brought indoors; however, before the end of the 36-day period prior to treatment, the leaves of the plants, in most instances, were yellow. After chemical treatment, all plants became dry and looked as if dead; at this time green tissue could be found only at the bases of the culms and stolons.

Reference to Table II shows that in no instances

was the rest period broken by chemical treatment; chemically treated plants and control plants began growth 54 days after treatment.

All plants treated with 2.0 and 1.0 per cent concentrations of the solution were killed.

Vegetative growth was greatly stimulated by supplemental light, long-day controls having grown more than twice as tall as short-day controls. In all but a few instances the solution stimulated growth.

Plants frozen out-of-doors began to grow 4 days after having been brought inside. At the end of the experiment they had not made as much growth as had the treated plants.

Chemical treatment seemed to inhibit flowering, for in both series the controls produced flowers as early as and more abundantly than did the chemically treated plants. Flowers appeared 81 days after treatment on both long-day and short-day controls. The flowering response to chemical treatment was very erratic; some long-day plants treated with 0.1 per cent chemical flowered 81 days after treatment, while those treated with 0.01 per cent chemical flowered 140 days after treatment. Short-day plants given a 0.01 per cent concentration of the solution flowered 86 days after treatment.

Table II. Effect of Potassium Thiocyanate, Supplemental Light and Out-door Freezing upon Buffalo Grass.

Treatment	Effect of Treatment: Averages				
	No. of days after treatment until growth began	Average Height (cm)		Per cent survival	No. of days after treatment until flowers appeared
		95 days after treatment	140 days after treatment		
Long-day Series					
Control	54	16	29	96	81
2.0 % KSCN	dead	dead	dead	dead	
1.0 % "	dead	dead	dead	dead	
0.5 % "	54	11	17	62	
0.1 % "	54	13	35	96	81
0.01 % "	54	20	34	98	140
0.001 % "	54	12	30	98	
Out-door Freezing	4*	15	31	98	
Short-day Series					
Control	54	12	12	98	81
2.0 % KSCN	dead	dead	dead	dead	
1.0 % "	dead	dead	dead	dead	
0.5 % "	54	10	10	97	
0.1 % "	54	11	11	98	
0.01 % "	54	12	12	98	86
0.001 % "	54	11	11	98	
Out-door Freezing	4*	9	9	98	

* Number of days after frozen plants were brought into the green-house on December 30 until growth began.

TALL GRASSES

Tall Grama Grass

Tall grama grass, prior to treatment, reacted much as did the short grasses. It remained green for several weeks, making little or no growth and gradually becoming light green and then yellow in color until at the time of treatment the plants were dormant and sere.

Twenty-one days after treatment, green leaves were observed to be bursting from the sides of the dead culms of some plants and protruding up through them (Table III). As Fig. 4 shows, this response to chemical treatment was very erratic; 2.0 per cent, 1.0 per cent, 0.1 per cent, and 0.001 per cent concentrations were effective in breaking the rest period in long-day plants, while 2.0 per cent, and 0.01 per cent concentrations broke the rest period in the short-day plants. The long-day control plants began growth 69 days after treatment. Only one concentration failed to break the rest period in at least one series; this was a 0.5 per cent concentration. Frozen plants resumed growth 4 days after they were brought indoors.

Table III. Effect of Potassium Thiocyanate, Supplemental Light, and Out-door Freezing upon Tall Grama Grass.

Treatment	Effect of Treatment: Averages			
	No. of days after treatment until growth began	Average Height (cm)		Per cent survival
		95 days after treatment	140 days after treatment	
Long-day Series				
Control	69	4	12	65
2.0 % KSCN	21	14	31	25
1.0 % "	21	14	37	50
0.5 % "	53	19	32	50
0.1 % "	21	26	22	55
0.01 % "	69	20	30	75
0.001 % "	21	17	36	50
Out-door Freezing	4*	31	45	98
Short-day Series				
Control	54	9	9	52
2.0 % KSCN	21	12	12	5
1.0 % "	54	14	14	45
0.5 % "	54	15	15	50
0.1 % "	54	14	14	65
0.01 % "	21	14	14	60
0.001 % "	62	10	10	85
Out-door Freezing	4*	13	13	95

* Number of days after frozen plants were brought into the green-house on December 30 until growth began.

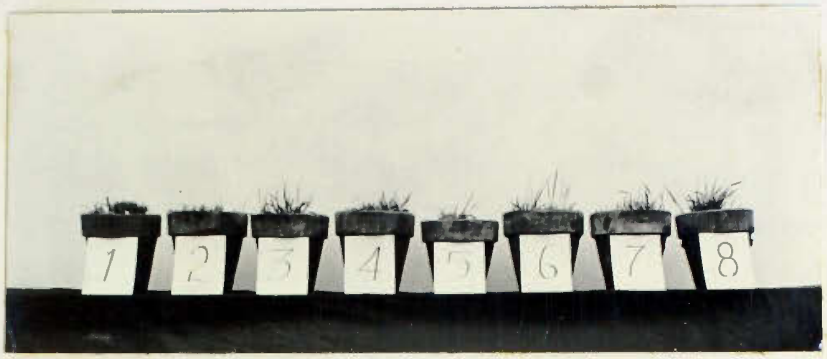


Fig. 4. Tall Grama Grass: long-day series. Shows erratic response to chemical treatment. Photograph taken 54 days after treatment. (1) Control, (2) 2.0 per cent, (3) 1.0 per cent, (4) 0.5 per cent, (5) 0.1 per cent, (6) 0.01 per cent, (7) 0.001 per cent, (8) Frozen.

Growth was greatly stimulated in both short and long-day plants by chemical treatment (Fig. 5). Supplemental light alone stimulated growth only a little; the combined action of the chemical and supplemental light produced nearly three times as much growth as did chemical alone (Fig. 5).

Fig. 5. Tall Grama Grass.
Shows stimulating effect of chemical and supplemental light. Photograph taken 95 days after treatment. Short-day: (1) Control, (2) 0.1 per cent. Long-day: (3) Control, (4) 0.1 per cent.

While concentrations of chemical most effective in breaking the rest period induced, on the average, slightly greater growth than did other concentrations, in most instances they had a killing effect as judged by per cent survival and foliage appearance. In the long-day series, plants which had been frozen produced more growth than did those that were treated with the solution.

Western Wheat Grass

Western wheat grass was green and growing when first placed in the greenhouse. Unlike the other grasses it did not become yellow and cease growing during the 36-day

period before treatment, but grew rapidly. After treatment, both long-day and short-day plants treated with the solutions of 2.0 per cent and 1.0 per cent concentrations died (Figs. 6,7). All other plants continued growth without interruption for the duration of the experiment (Table IV). Plants frozen out-of-doors began growth 4 days after having been brought indoors.

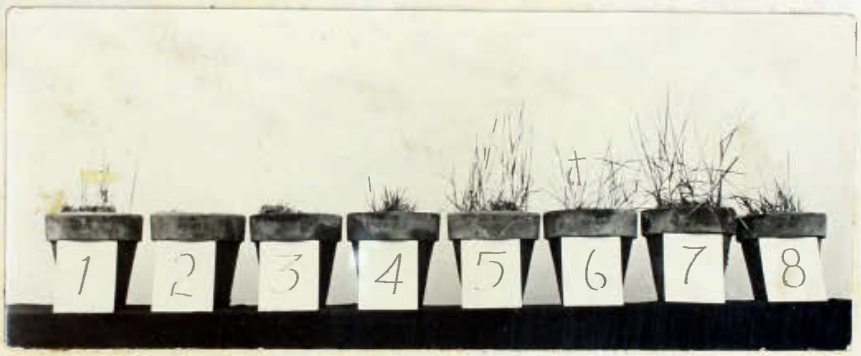


Fig. 6. Western Wheat Grass: long-day series. Shows the killing effect of 2.0 and 1.0 per cent solutions. Photograph taken 54 days after treatment. (1) Control, (2) 2.0 per cent, (3) 1.0 per cent, (4) 0.5 per cent, (5) 0.1 per cent, (6) 0.01 per cent, (7) 0.001 per cent, (8) Frozen.

Fig. 7. Western Wheat Grass: short-day series. Shows the killing effect of 2.0 and 1.0 per cent solutions. Photograph taken 54 days after treatment. (1) Control, (2) 2.0 per cent, (3) 1.0 per cent, (4) 0.5 per cent, (5) 0.1 per cent, (6) 0.01 per cent, (7) 0.001 per cent, (8) Frozen.

Supplemental light greatly stimulated growth; long-day control plants produced more than twice as much growth as did the short-day controls (Fig. 8).

Plants which received both chemical treatment and supplemental light produced two times as much growth as did plants which received only supplemental light (Fig. 9). In the short-day series, frozen plants and chemically treated plants made approximately the same amount of growth.

No plants flowered during the experiment.

Table IV. Effect of Potassium Thiocyanate, Supplemental Light, and Out-door Freezing Upon Western Wheat Grass.

Treatment	Effect of Treatment: Averages			
	No. of days after treatment until growth began	Average Height (cm)		Per cent survival
		95 days after treatment	140 days after treatment	
Long-day Series				
Control	1	23	37	98
2.0 % KSCN	dead	dead	dead	
1.0 % "	dead	dead	dead	
0.5 % "	1	13	30	1
0.1 % "	1	38	47	98
0.01 % "	1	36	47	74
0.001 % "	1	39	48	98
Out-door Freezing	4*	32	46	98
Short-day Series				
Control	1	16	16	98
2.0 % KSCN	dead	dead	dead	
1.0 % "	dead	dead	dead	
0.5 % "	1	11	11	65
0.1 % "	1	13	13	98
0.01 % "	1	17	17	98
0.001 % "	1	16	16	98
Out-door Freezing	4*	18	18	98

* Number of days after frozen plants were brought into the green-house on December 30 until growth began.

Fig. 8. Western Wheat Grass. Shows the stimulating effect of chemical and supplemental light. Photograph taken 95 days after treatment. Short-day: (1) Control, (2) 0.001 per cent. Long-day: (3) Control, (4) 0.001 per cent.

Fig. 9. Western Wheat Grass: long-day series. Contrasts the effect of chemical and freezing upon growth. Photograph taken 95 days after treatment. (1) Control, (2) 0.001 per cent, (3) Frozen.

Big Bluestem Grass

Big bluestem grass remained green only a short time after having been placed in the greenhouse. It did not produce any growth prior to treatment, but gradually became red and sere until 69 days after treatment it was considered dead. At this time, sprouts were observed to be protruding from the crown of some of the sods (Table V). The long-day and short-day controls began growth 81 and 75 days, respectively, after treatment. With the exception of the 2.0 per cent concentration which had a killing effect, all concentrations of chemical produced a slight initiating response. Frozen plants in long and short-day series resumed growth 22 and 8 days, respectively, after having been brought indoors.

Neither supplemental light nor chemical treatment when acting alone stimulated growth perceptibly. Supplemental light acting together with chemical treatment, however, induced twice as much growth as did chemical treatment alone. Frozen plants in the long-day series did not produce as much growth as did chemically treated plants. Frozen plants in the short-day series and plants that had received chemical treatment produced approximately the same amount of growth, but frozen plants produced more growth than those given no treatment at all.

No big bluestem plants flowered during the experiment.

Table V. Effect of Potassium Thiocyanate, Supplemental Light, and Out-door Freezing upon Big Bluestem Grass.

Treatment	Effect of Treatment: Averages			
	No. of days after treatment until growth began	Average Height (cm) 95 days after treatment	Average Height (cm) 140 days after treatment	Per cent survival
Long-day Series				
Control	81	11	20	98
2.0 % KSCN	81	14	20	1
1.0 % "	69	22	35	25
0.5 % "	69	16	32	50
0.1 % "	69	23	40	90
0.01 % "	69	8	8	1
0.001 % "	69	24	26	1
Out-door Freezing	22*	16	33	98
Short-day Series				
Control	75	15	15	95
2.0 % KSCN	dead	dead	dead	
1.0 % "	69	14	14	20
0.5 % "	69	15	15	60
0.1 % "	69	17	17	75
0.01 % "	69	16	16	50
0.001 % "	69	12	12	2
Out-door Freezing	8*	17	17	98

* Number of days after frozen plants were brought into the green-house on December 30 until growth began.

General Results

Although nearly all concentrations of the solution were effective to some degree in breaking the rest period of blue grama grass, tall grama grass, and big bluestem grass, the concentrations most effective ranged below 0.5 per cent. Concentrations of 0.5 per cent and greater, while effective, in some instances of breaking the rest period, usually had a killing effect. The plants which received strong chemical treatment had the tips of their leaves burned by the chemical. Although some plants in tall grama grass sods treated with 1.0 and 2.0 per cent concentrations of chemical began growing early and made much growth, many of the plants in the sods were killed (Table III).

In all instances, grasses treated with chemical were lighter green in color than were untreated plants. This was most noticeable in western wheat grass which showed very pronounced color variations due to differences in solution concentrations.

Weak concentrations of solution, even though they did not break the rest period, stimulated growth. This was especially noticeable in buffalo grass plants which received illumination supplemental to daylight (Table II).

Chemical treatment had no effect on the number of stolons produced, but it did stimulate growth in length of stolons.

Supplemental illumination in all instances was very effective in stimulating vegetative growth. Plants in the long-day series, as contrasted with those in the short-day series, were in general more vigorous. The leaves and stems were narrower and lighter in color, and there was less pubescence on grasses where it is normally present. This agrees with the findings of Popp (14), and of Ramaley (15). Long-day plants, in accord with the findings of Weaver and Himmel (10), developed more extensive root systems than did short-day plants.

Chemical treatment did not induce flowering, for the control plants in both series flowered more profusely than did treated plants. Long-day treatment stimulated flowering in blue grama grass. Perhaps a day length intermediate between that given the two series would have induced flowering in tall grama grass and western wheat grass [Evans and Allard (12), Emerson (11)].

Plants late to begin growing grew rapidly and by the end of the experiment had produced as much growth as had those that began growing earlier. This was especially true of plants which had received out-of-door freezing.

SUMMARY

Some sods of 5 mid-western grasses were treated with potassium thiocyanate, some subjected to out-door freezing, and then some of each of these were given light supplemental to daylight in the attempt to break their rest period and to stimulate growth.

The rest period of blue grama grass and tall grama grass was effectively broken 21 days after treatment with solutions of potassium thiocyanate. A slight initiating response was caused also in big bluestem grass by chemical treatment. The most effective strength of solution was a 0.1 per cent concentration.

Chemical treatment was not effective in breaking the rest period of buffalo grass; chemically treated and control plants began growth 130 days after having been brought indoors, or 54 days after treatment.

Western wheat grass appears to have no rest period; it began growth immediately upon being brought indoors, and continued growing for the duration of the experiment.

In most instances, chemical and supplemental light stimulated growth in height.

In the majority of cases 2.0 and 1.0 per cent concentrations of chemical killed plants so treated.

Chemical treatment seemed to inhibit flowering of buffalo grass. Supplemental light was conducive to the flowering of blue grama grass.

Frozen plants of big bluestem grass in the long-day and short-day series began growth 22 and 8 days respectively after having been brought indoors on December 30; plants of all other grasses frozen out-of-doors began growth 4 days after they were brought inside. In nearly all instances these plants had made as much growth by the end of the experiment as had the treated plants.

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5. _____ and Miller, Lawrence P. Hastening the germination of dormant gladiolus cormels with vapors of ethylene chlorhydrin. Yonkers, N. Y., Boyce Thompson Institute for Plant Research, 1934. 8 p. (Reprinted from Contributions from Boyce Thompson Institute, vol. 6, no. 1, p. 31-38. 1934).

Contains good material on methods of treatment.

6. Stanton, E. N. and Denny, F. E. Forcing dormant woody plants with chemical vapors. Yonkers, N. Y., Boyce Thompson Institute for Plant Research, Professional paper no. 10, March, 1929. 10 p. (Reprinted from Florists Exchange and Horticultural Trade World, vol. 70, no. 10, p. 11, 15, 36. March 9, 1929).

Lilac, crab apple, grape, wisteria, astilbe forced into early flowering by treatments with vapors of ethylene dichloride and ethylene chlorhydrin.

7. Garner, W. W. Comparative responses of long-day and short-day plants to relative length of day and night. [n.p., 1932]. (Reprinted from Plant Physiology, vol. 8, p. 347-356. 1932).

Deals with the reproductive activity as controlled by day-length.

8. Garner, W. W. and Allard, H. A. Localization of the response in plants to relative length of day and night. Washington, D. C., Government printoffice, Sept. 15, 1925. 12 p. (Reprinted from Journal of Agricultural Research, vol. 31, no. 6. p. 555-566. Sept. 15, 1925).

Different portions of primary stem of Cosmos are exposed to different daily periods of illumination in an attempt to localize seat of flowering response.

9. _____ Duration of the flowerless condition of some plants in response to unfavorable lengths of day. Washington, D. C., Government printing office, 1931. 5 p. (Reprinted from Journal of Agricultural Research, vol. 43, no. 5, p. 439-443. Sept. 1, 1931).

Proof that unfavorable length of day will hold plants from flowering as long as short days are allowed to operate.

10. Weaver, J. E. and Himmel, W. J. Relation between the development of root system and shoot under long-day and short-day illumination. [n.p., 1929]. [22 p.] (Reprinted from Plant Physiology, vol. 4, p. 435-457, 1929).

Shows that development of root systems in oats is in direct correlation with the development of tops.

11. Emerson, R. A. Control of flowering in teosinte. Ithaca, N. Y., Paper no. 16, Department of Plant Breeding, Cornell University, [1924]. 8 p. (Reprinted from Journal of Heredity, Washington, D. C., vol. 15, no. 1, p. 41-48. Jan., 1924).

Gives the effect of short-day treatment upon flowering.

12. Evans, Morgan W. and Allard, H. A. Relation of length of day to growth of timothy. Washington, D. C., Government printing office, 1934, 16 p. (Reprinted from Journal of Agricultural Research, vol. 48, no. 7, p. 571-586. April 1, 1934).

An excellent presentation of the relative effects of long and short-day treatment. Contains many good photographs.

13. Laurie, Alex and Poesch, G. H. Photoperiodism--the value of supplementary illumination and reduction of light on flowering plants in the greenhouse. Wooster, Ohio. 1932. 42 p. (Agricultural Experiment Station Bul. no. 512. October, 1932).

Contains some specific recommendations for lighting equipment.

14. Popp, W. Henry. Effect of light intensity on growth of soy beans and its relation to the autocatalyst theory of growth. [Philadelphia, 1926.] [14 p.] (Contributions from the Hull Botanical Laboratory 357, Reprinted from the Botanical Gazette, vol. 82, no. 3, p. 306-319. Nov., 1926).

Gives effect of light intensity upon vigor of plant and thickness of stem.

15. Ramaley, Francis. Influence of supplemental light on blooming. [Philadelphia 1934.] 1934. 10 p. (Reprinted from the Botanical Gazette, vol. 96, no. 1, p. 165-174. Sept., 1934).

Gives effect of supplemental light upon height, color, and vigor of plants.