THE INFLUENCE OF DAYLENGTH AND TEMPERATURE ON THE GROWTH AND FLOWERING OF CALLISTEPHUS CHINENSIS NEES

Thesis for the Degree of M. S.

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Lok-chien Lin

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THESIS

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__________ degree in __________

Donald P. Watson
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THE INFLUENCE OF DAYLENGTH AND TEMPERATURE ON THE GROWTH AND FLOWERING OF CALLISTEPHUS CHINENSIS NEES.

By

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A THESIS

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Introduction

During the late winter and early spring months the China aster (_Callistephus chinensis Nees._) is frequently grown in the greenhouse as a cut flower crop. It has previously been shown by Post (14) in 1935 that the growth of this plant is influenced by the length of the light period and the temperature at which it is grown. The commercial grower is usually interested in timing the flowering date to coincide with the greatest demand for his crop. Consequently it is important to him to be able to take advantage of these factors, both so that he can produce his crop when he wishes and also in as short a period as is practical.

Table I shows that the days at East Lansing from August 13 to April 29 are too short for China asters to form flower buds when axis elongation occurs. This experiment is a study of the influence of daylength and temperature on the growth and flowering of _Callistephus chinensis Nees._ Plants were grown with and without artificial light in Michigan State College greenhouses, East Lansing, Michigan, during the period from October 1948 to April 1949.

Table I. Daylength throughout the Year from Sunrise to Sunset, as Compiled at East Lansing, Michigan
Presented in Hours and Minutes (U. S. Department of Commerce)

Day of Month	Month											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	9' 7"	9'59"	11'12"	12'43"	14' 5"	15' 6"	15'17"	14'30"	13'11"	11'45"	10'20"	9'18"
2	9' 7"	10' 2"	11'15"	12'46"	14' 7"	15' 8"	15'16"	14'27"	13' 9"	11'42"	10'17"	9'16"
3	9' 8"	10' 4"	11'19"	12'49"	14' 9"	15' 9"	15'16"	14'25"	13' 6"	11'39"	10'15"	9'15"
4	9' 9"	10' 6"	11'21"	12'53"	14'12"	15'10"	15'14"	14'22"	13' 3"	11'37"	10'13"	9'14"
5	9'10"	10' 9"	11'24"	12'55"	14'14"	15'11"	15'13"	14'20"	13' 0"	11'34"	10'11"	9'13"
6	9'12"	10'12"	11'27"	12'58"	14'16"	15'11"	15'13"	14'17"	12'58"	11'30"	10' 7"	9'10"
7	9'13"	10'14"	11'29"	13' 1"	14'19"	15'13"	15'11"	14'15"	12'55"	11'27"	10' 5"	9'10"
8	9'14"	10'17"	11'33"	13' 3"	14'22"	15'14"	15'10"	14'13"	12'51"	11'25"	10' 3"	9' 9"
9	9'15"	10'19"	11'36"	13' 6"	14'24"	15'15"	15'10"	14'10"	12'48"	11'22"	10' 1"	9' 8"
10	9'16"	10'21"	11'39"	13' 9"	14'26"	15'15"	15' 8"	14' 8"	12'46"	11'19"	9'58"	9' 7"
11	9'18"	10'24"	11'41"	13'11"	14'28"	15'17"	15' 7"	14' 6"	12'43"	11'17"	9'56"	9' 6"
12	9'19"	10'27"	11'45"	13'15"	14'31"	15'17"	15' 5"	14' 3"	12'40"	11'13"	9'54"	9' 5"
13	9'20"	10'29"	11'48"	13'18"	14'33"	15'17"	15' 4"	14' 1"	12'37"	11'10"	9'51"	9' 5"
14	9'22"	10'31"	11'50"	13'20"	14'35"	15'18"	15' 3"	13'58"	12'34"	11' 8"	9'49"	9' 4"
15	9'24"	10'35"	11'53"	13'23"	14'37"	15'19"	15' 1"	13'56"	12'32"	11' 5"	9'47"	9' 4"
16	9'26"	10'36"	11'56"	13'25"	14'39"	15'19"	15' 0"	13'53"	12'29"	11' 2"	9'45"	9' 3"
17	9'27"	10'39"	12' 0"	13'28"	14'41"	15'19"	14'58"	13'51"	12'25"	11' 0"	9'43"	9' 3"
18	9'29"	10'43"	12' 3"	13'31"	14'43"	15'20"	14'58"	13'47"	12'22"	10'54"	9'40"	9' 3"
19	9'30"	10'45"	12' 5"	13'32"	14'45"	15'20"	14'54"	13'45"	12'19"	10'56"	9'38"	9' 2"
20	9'33"	10'48"	12' 8"	13'36"	14'47"	15'20"	14'54"	13'42"	12'17"	10'51"	9'37"	9' 2"
21	9'35"	10'50"	12'11"	13'39"	14'49"	15'20"	14'52"	13'40"	12'14"	10'49"	9'34"	9' 2"
22	9'36"	10'53"	12'14"	13'42"	14'51"	15'20"	14'50"	13'37"	12'11"	10'46"	9'32"	9' 2"
23	9'39"	10'56"	12'17"	13'44"	14'52"	15'20"	14'48"	13'35"	12' 8"	10'44"	9'31"	9' 2"
24	9'41"	10'59"	12'20"	13'47"	14'54"	15'20"	14'46"	13'32"	12' 5"	10'40"	9'29"	9' 3"
25	9'43"	11' 1"	12'23"	13'49"	14'56"	15'19"	14'44"	13'30"	12' 3"	10'38"	9'27"	9' 3"
26	9'46"	11' 4"	12'26"	13'52"	14'58"	15'19"	14'42"	13'26"	12' 0"	10'36"	9'25"	9' 3"
27	9'48"	11' 7"	12'28"	13'54"	14'59"	15'19"	14'40"	13'24"	11'57"	10'33"	9'23"	9' 3"
28	9'49"	11'10"	12'31"	13'56"	15' 1"	15'18"	14'39"	13'22"	11'53"	10'31"	9'22"	9' 3"
29	9'51"	11'12"	12'35"	13'59"	15' 3"	15'18"	14'36"	13'19"	11'50"	10'27"	9'20"	9' 4"
30	9'54"		12'38"	14' 2"	15' 4"	15'17"	14'34"	13'17"	11'48"	10'25"	9'19"	9' 5"
31	9'56"		12'41"		15' 5"		14'31"	13'14"		10'23"		9' 6"

Review of Literature

The first record of the effect of light upon plants was made by John Ray in 1686 (Laurie and Poesch 12), who found in Historia Plantarum differences due to light variation. It was fully two centuries later before any comprehensive research along this line was undertaken. The earliest horticulturist in this country who brought to the public the study of the influence of electric lamp upon greenhouse plants was L. H. Bailey (1). He used radishes, peas, lettuce, tulips, verbenas, and petunias as material and found that "the electric light promotes assimilation; it often hastens growth and maturity; it is capable of producing natural flowers and colors in fruits; it often intensifies colors of flowers and sometimes increases the production of flowers. The experiments show that periods of darkness are not necessary to the growth and development of plants."

Stone (20) found that light has an important influence on the configuration of plants. Since most of the plant energy is derived from the air through sunlight, the optimum light conditions were important, and there was a marked difference in the light requirements of carnations, roses, lettuce, cucumbers and tomatoes. In 1920, Garner and Allard (5) published the results of tests on the effects of the relative length of day and night and other factors of the environment on growth of asters, soybeans, tobacco, climbing beans, violets, and other vegetables. Duration of the flowerless condition of some plants in response to shortened days may continue for years.

Garner and Allard (6) found further that relatively short alternating cycles of light and darkness tend to produce effects similar to those of a long day or of continuous light in that they favor flowering in long day plants but not in short day plants. A suggestion by Kellerman (10) is that the plant could belong to the long or short day group since some varieties bloom when the light periods are less than 12 hours if the equational length of day of 12 hours is regarded as a standard.

Poesch and Laurie (13) classify China aster (variety Sunshine) as a long day plant. While it blooms after August 15 when the days in the north of the hemisphere are rapidly becoming shorter, its flowers are probably initiated earlier in the season. Their results are based on the affects of additional light during the winter, which was found to reduce the time necessary for flowering.

Greene, Withrow and Richman (7) have shown that the short day months increase the time required for flowering. They found that artificial light supplementing daylight made possible the production of an early spring crop of asters of excellent quality.

Withrow and Benedict (22) found that under conditions used in these experiments the light from a 15-watt lamp placed 4 feet above the bench and applied for 10 hours each night is nearly as effective in the winter forcing of good quality flowers (China aster variety "Heart of France") as a 500-watt lamp producing approximately 75 times the visible light and applied under the same conditions. Withrow (23) showed that favorable results were obtained by using high intensity lights for a few weeks to hasten flowering. Low intensity lights produced extremely variable results.

Short stems developed at high temperatures in short days for Biebel (3). He was able to produce the normal habit only with long days. A temperature of 70° F. affected not only the time of flowering in China aster and the inflorescence produced but sometimes caused flowering despite unfavorable length of days (Biebel 4).

Post (15) found that additional light in the early stages of growth made the plants start to flower from 12 to 23 days earlier than in the checks, depending upon the time of propagation. Higher temperature with the additional light further hastened the time of bloom of light-treated plants. The production and quality were further reduced by the higher temperature under long days.

With regard to the responses of <u>Callistephus chinensis</u> <u>Nees.</u> Post (16) showed that the use of artificial light during the short days from September to May prevented rosetting and caused elongation of the plant stems followed by flower-bud formation. The reduction of the day length, which can hasten the results, caused short stems and small flowers. Temperatures above 65° F. caused slight stem elongation so that even during short days buds might form and develop into flowers. Post (14) concluded that the additional day length in the early period of growth followed by reduced day length during summer after buds had developed produced earlier flowers of normal size on late types than other treatments.

Post (18) maintains further that from the temperature standpoint there were three groups of plants: (a) those requiring low temperature for bud formation and producing vegetative growth at high temperatures, (b) those requiring high temperature for flower bud formation and producing vegetative growth at low temperature, and (c) those requiring high temperature for growth and flowering.

Honeywell (9) demonstrated that artificial lighting on aster seedlings immediately after germination resulted in flowering as much as two weeks earlier under field conditions. Artificial light supplementing daylight during early October, five hours at night using 25-watt lamps, made possible the production of a mid-winter crop of greenhouse asters of excellent quality. In 1948 Withrow (21) published an article on artificial lighting for forcing greenhouse crops. He recommended that the period for lighting for winter forcing of asters begin at six weeks or more after seeding and continue until buds set and stems reach desired length. Certain conditions of the environment, specifically a long day and definite temperature, are necessary for most rapid seed germination, growth, and flowering of these plants (3, 12, 14). Optimum temperature for seed germination is between 60° and 65° F. (9). Flower buds do not initiate when the temperature is below 50° F. or when the light period is less than 15 hours (18).

Taking advantage of this information, this study was undertaken to attempt to learn: (a) the number of days required to produce flowers on plants which are being grown at high and low temperatures and with long and short days, and (b) the variations in growth habit caused by different temperatures and day lengths. From these data it would seem likely that more accurate recommendations could be made to growers who desire to closely limit the time of flowering or to alter the stem length or overall form of their plants.

Materials and Methods

China aster (variety Sensation) was grown in the greenhouse. Seeds were sown in sandy soil in a greenhouse maintained at 65° F. on October 30, 1948. After 37 days (December 6, 1948), 120 seedlings were transplanted into 2½-inch clay pots and then divided into two groups to be grown at 50° F. (low temperature) and 65° F. (high temperature), respectively. One hundred and six days later (March 22, 1949) they were repotted into 5-inch clay pots.

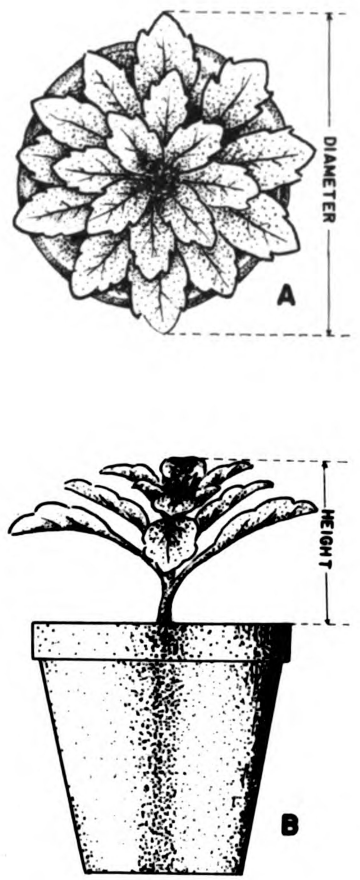
As soon as the plants were transplanted, artificial light was used on 30 low temperature seedlings and on 30 high temperature seedlings. This artificial light was produced from a 60-watt, 120-volt incandescent lamp suspended 2½ inches above the plants. From December 6, 1948 to March 31, 1949, this light was used five hours after sunset every day. This made a total of four groups of plants: (a) low temperature long day, (b) low temperature short day, (c) high temperature long day, and (d) high temperature short day. Thus the day length treatment with this additional light is termed "long day" and without it, "short day".

Records were kept of (a) diameter and height of plants every 15 days between the 68th day and 158th day after seeding (Tables IV and V and Fig. I, A and B) and (b) the time of appearance of first buds and first full bloom on each plant until there was a total of approximately 50 buds or flowers for each group of 20 plants.

Collections were made at 15-day intervals (between the 68th day and 158th day after seeding) of: (a) leaves produced under each growing condition (Fig. II, A), and (b) whorl of young leaves at center of growing axis where flower initiation was likely to be present (Fig. II, B).

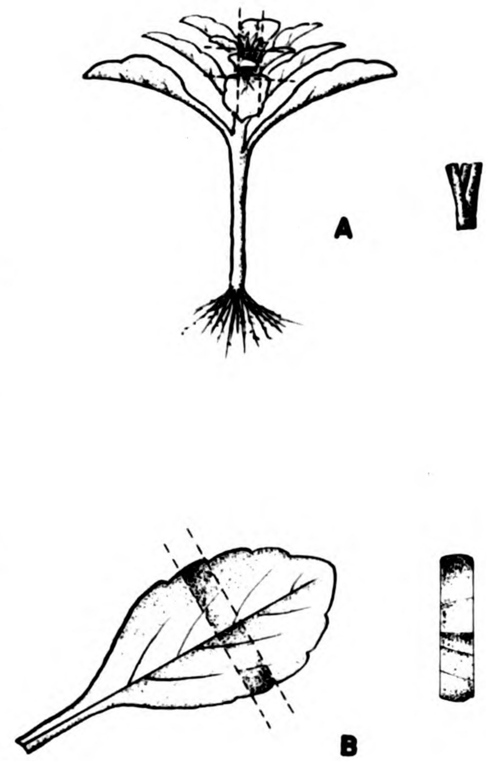
All plant material was preserved in formalin-aceto-alcohol (50% ethyl alcohol 90 cc., glacial acetic acid 5cc., formalin 5 cc.). The material was then dehydrated in the usual manner for paraffin imbedding. It was cut on a rotary microtome ten micra in thickness and stained with saffranin and Heindenhain's haematoxylin. Permanent sections were mounted in Canada balsam. Three hundred and sixty permanent slides were made for the whole study.

Fig. I.



METHOD OF MEASUREMENT

Fig. II.



METHOD OF COLLECTION

Presentation of Data

Table II and Figure III indicate that on the "high temperature, long day" plants, buds were visible on the 150th day after seed sowing. They formed 49 buds between then and the 163rd day. On the "high temperature, short day" plants, buds were visible on the 165th day after seed sowing. They formed 47 buds between then and the 187th day. On the "low temperature, long day" plants, buds were visible on the 151st day after seed sowing. They formed 47 buds between then and the 168th day. On the "low temperature, short day" plants buds were visible on the 176th day after seed sowing. They formed 49 buds between then and the 199th day.

Table III and Figure IV indicate that on the "high temperature, long day" plants flowers were visible on the 165th day after sowing. They formed 45 flowers between then and the 180th day. On the "high temperature, short day" plants flowers were visible on the 179th day after seed sowing. They formed 50 flowers between the 179th and 202nd day. On the "low temperature, long day" plants, flowers were visible on the same date as on the "high temperature, long day" plants. But the "low temperature, long day" plants did not develop fully open flowers until 4 days later than the "high temperature, long day" plants. On the "low temperature, short day" plants a flower was visible on the 192nd day after the seed sowing. They formed 46 flowers between then and the 215th day.

Table IV and Figure V show that on the 68th day after sowing (January 6, 1949), the average diameter of the "high temperature, long day" plants was 7.11 cm.; the average diameter of the "high temperature, short day" plants, 5.93 cm.; the average diameter of the "low temperature, long day" plants, 6.52 cm.; and of the "low temperature, short day" plants, 4.82 cm. Measurements were taken at 15-day intervals. On the 158th day after the seed sowing (April 6, 1949), the average diameter of "high temperature, long day" plants was 15.28 cm.; the average diameter of the "high temperature, short day" plants, 12.86 cm.; the average diameter of the "low temperature, long day" plants, 13.84 cm.; and the average diameter of the "low temperature, short day" plants, 11.30 cm. Briefly, the greatest plant diameter was obtained where plants were subjected to a long day light period and high temperature (Fig. VII and VIII).

From Table V and Fig. VI it is observed that on the 98th day after seed sowing (February 5, 1949), the average height of the "high temperature, long day" plants was 7.68 cm.; the average height of the "high temperature, short day" plants was 2.20 cm.; the average height of the "low temperature, long day" plants was 3.15 cm.; and the average height of the "low temperature, short day" plants was 2.45 cm. Measurements were taken every 15 days. On the 158th day after seed sowing (April 6, 1949), the average height of the "high temperature, long day" plants was

13.12 cm.; the average height of the "high temperature, short day" plants was 6.71 cm.; the average height of the "low temperature, long day" plants was 8.69 cm.; and the average of the "low temperature, short day" plants was 5.63 cm. "Long day, high temperature" environment resulted in greater length growth (Fig. VII and VIII).

Table IV shows that the average diameter of plants at high temperature was 1.91 cm. more than without additional light, and at low temperature the diameter was 2.20 cm. more than without additional light.

Table V shows that the average height of plants at high temperature was 6.18 cm. more than without additional light and at low temperature was 2.31 cm. more than without additional light.

Table II. Influence of Temperature and Daylength on Accumulative Bud Development. (data in number of buds)

Days after seeding	High temperature		Low temperature	
	Long day	Short day	Long day	Short day
150	7			
151	10		3	
152	10		4	
153	11		4	
154	14		7	
155	20		10	
156	23		13	
157	29		16	
158	34		20	
159	39		21	
160	40		22	
161	44		24	
162	45		27	
163	49		30	
164			31	
165		3	33	
166		3	38	
167		4	39	
168		5	45	
169		7	47	
170		8		
171		8		

Table II. Continued

Days after seeding	High temperature Long day	Short day	Low temperature Long day	Short day
172		9		
173		12		
174		15		
175		15		
176		16		1
177		19		3
178		22		7
179		22		7
180		24		12
181		27		13
182		29		15
183		30		16
184		33		19
185		38		19
186		43		23
187		47		25
188				30
189				32
190				32
191				34
192				34
193				37
194				40

Table II. Continued

Days after seeding	High temperature		Low temperature	
	Long day	Short day	Long day	Short day
195				43
196				43
197				45
198				45
199				49

Table III. Influence of Temperature and Daylength on Flower Development. (data in number of flowers)

Days after seeding	High temperature Long day	High temperature Short day	Low temperature Long day	Low temperature Short day
165	7		4	
166	10		5	
167	14		5	
168	14		7	
169	19		9	
170	21		10	
171	24		12	
172	25		13	
173	28		16	
174	30		19	
175	32		23	
176	32		24	
177	39		25	
178	41		25	
179	42	1	28	
180	45	4	31	
181		7	34	
182		9	38	
183		9	41	
184		11	48	
185		14		
186		15		
187		19		
188		23		
189		26		

Table III. (Continued)

Days after seeding	High temperature Long day	Short day	Low temperature Long day	Short day
190		28		
191		29		1
192		35		1
193		35		1
194		35		3
195		39		6
196		41		9
197		41		10
198		43		16
199		45		16
200		45		16
201		47		18
202		50		23
203				25
204				25
205				29
206				33
207				36
208				36
209				37
210				40
211				43
212				43
213				43
214				45
215				46

FIG. III INFLUENCE OF TEMPERATURE AND DAYLENGTH ON BUD DEVELOPMENT

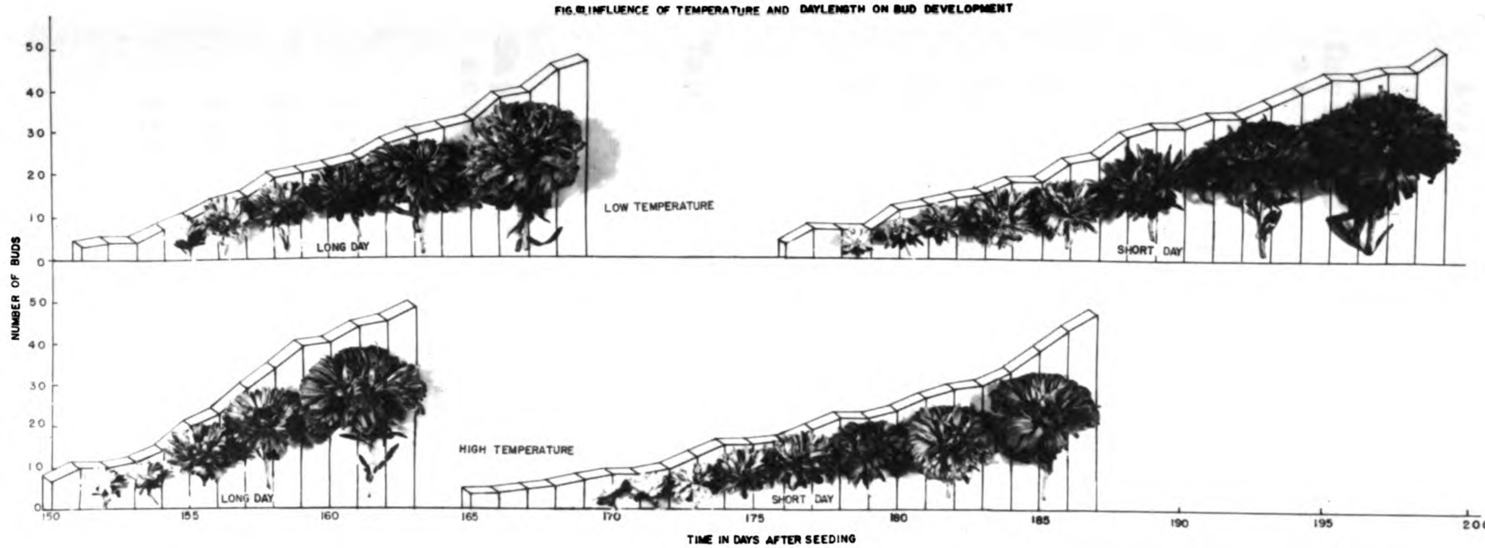


FIG. IV. INFLUENCE OF TEMPERATURE AND DAYLENGTH ON FLOWER DEVELOPMENT

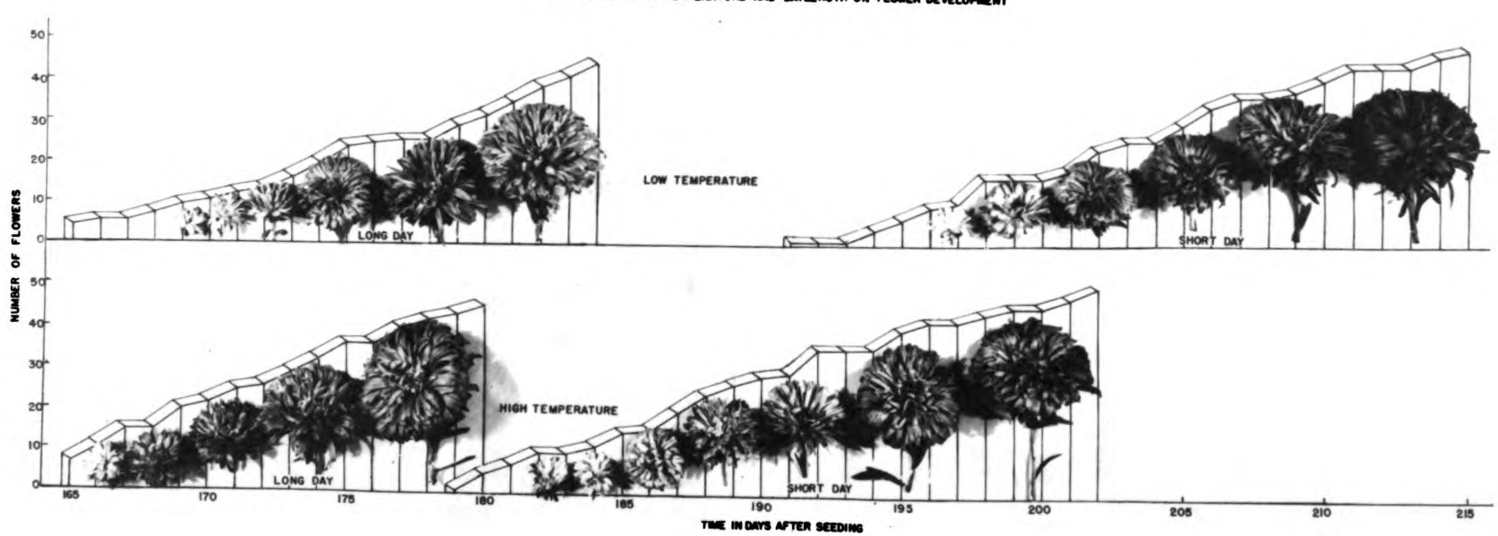


Table IV. Influence of Temperature and Daylength on Average Diameter Development of Plants (Produced from Table VI, data in cm.)

Days after seeding	High temperature		Low temperature	
	Long day	Short day	Long day	Short day
68	7.11	5.93	6.52	4.82
83	8.56	7.44	7.90	5.82
98	10.36	8.74	9.95	7.26
113	11.88	9.72	10.84	8.18
128	13.20	10.83	12.05	10.21
143	14.08	11.55	13.00	11.08
158	15.28	12.86	13.84	11.30

Table V. Influence of Temperature and Daylength on Average Height Development of Plants (Produced from Table VII, data in cm.)

Days after seeding	High temperature		Low temperature	
	Long day	Short day	Long day	Short day
98	7.68	2.20	3.15	2.45
113	8.84	3.41	4.77	2.99
128	10.13	4.23	6.41	3.69
143	12.58	4.88	7.45	4.45
158	13.12	6.71	8.69	5.33

Fig. V. INFLUENCE OF TEMPERATURE AND DAYLENGTH ON AVERAGE DIAMETER OF PLANTS

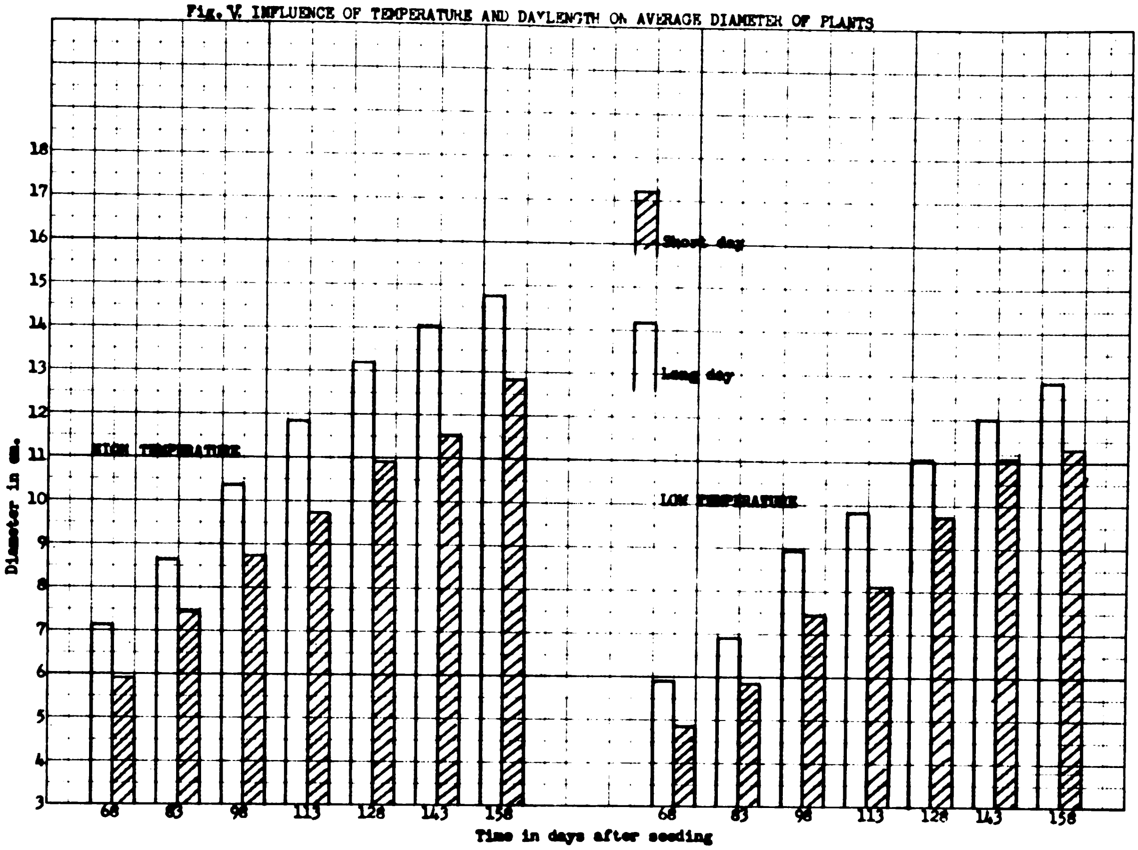


Fig. VI. INFLUENCE OF TEMPERATURE AND DAYLENGTH ON AVERAGE HEIGHT OF PLANTS

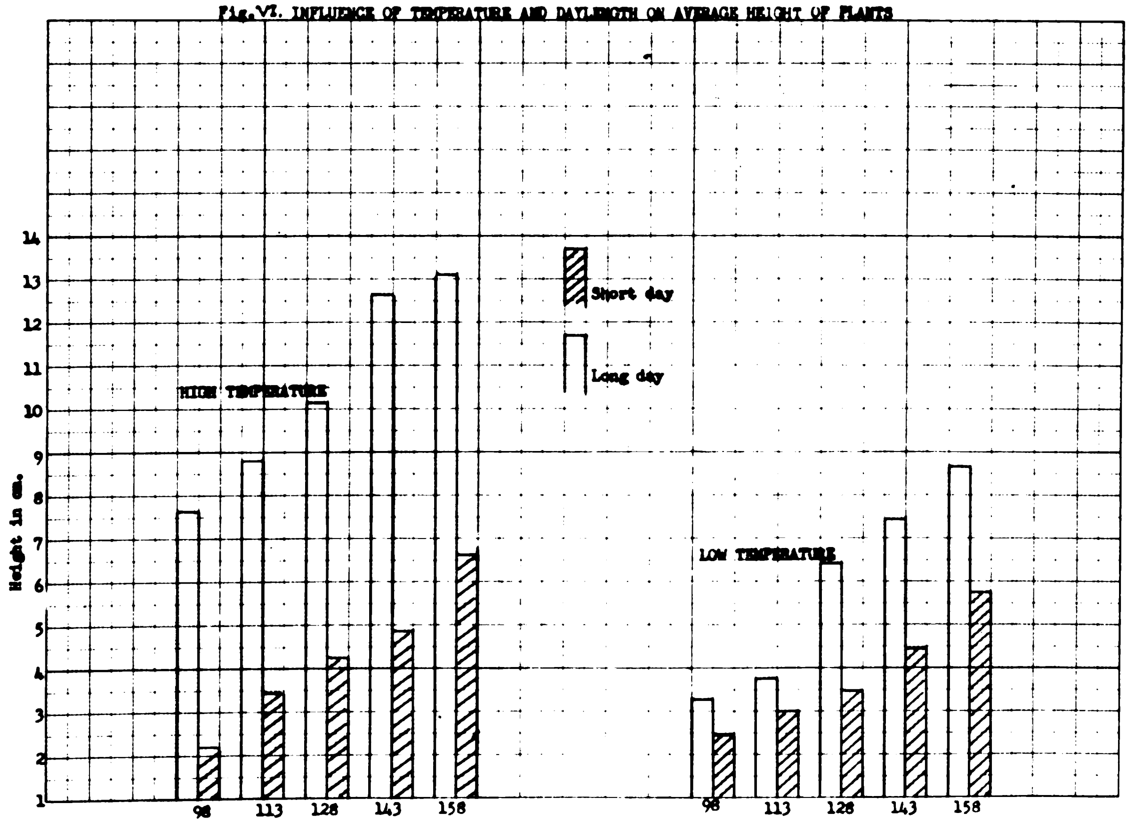


Table VI. Influence of Temperature and Daylength on Diameter Development of Plants (data in cm.)

Days after seeding	68th				83rd			
Temperature	High		Low		High		Low	
Daylength	Long	Short	Long	Short	Long	Short	Long	Short
Data of diameter on plants	7.0	7.3	7.1	5.0	9.7	8.7	9.2	5.6
	7.3	6.7	7.3	6.1	7.8	8.0	8.0	6.5
	6.9	7.3	7.0	5.2	7.5	8.5	9.1	5.5
	7.0	5.2	4.1	5.2	8.3	7.7	6.0	5.5
	8.8	6.5	6.0	4.0	9.4	7.8	7.0	6.5
	6.4	5.8	5.2	5.0	7.0	7.2	8.0	5.0
	6.8	4.2	6.0	5.0	10.5	6.6	10.0	6.0
	6.4	6.1	6.2	4.5	9.4	7.6	7.0	8.0
	6.0	5.1	6.0	5.2	7.6	7.6	10.8	6.0
	5.0	6.0	5.0	5.2	4.3	7.2	5.5	5.0
	6.0	6.8	9.0	5.0	7.4	7.0	10.9	7.0
	6.9	5.2	5.4	6.1	9.7	7.9	9.5	6.6
	8.9	6.0	8.5	5.1	9.8	6.8	10.0	5.6
	8.0	5.0	9.0	4.2	9.4	6.6	11.0	5.2
	7.0	6.3	7.0	6.1	9.4	7.0	9.5	7.0
	7.5	6.5	6.1	5.7	9.1	6.5	5.5	6.0
	8.2	5.0	7.0	2.3	9.2	6.8	9.0	3.0
	8.3	5.3	5.2	4.0	10.0	8.0	7.0	5.4
	6.6	5.8	6.1	3.0	8.0	7.0	6.5	4.8
	7.2	5.5	6.4	4.5	7.8	8.3	6.5	6.2
Average	7.11	5.93	6.52	4.82	8.59	7.44	7.9	5.82

Table VI. (Continued)

98th				113th				128th	
High		Low		High		Low		High	
Long	Short	Long	Short	Long	Short	Long	Short	Long	Short
11.5	9.0	10.2	6.5	14.0	9.6	10.8	7.5	15.0	10.0
10.5	10.0	9.1	8.0	11.5	10.7	10.3	8.5	13.1	10.8
9.0	9.0	12.0	7.0	11.0	9.2	12.6	8.2	13.1	10.6
9.6	8.0	7.5	7.1	13.0	8.5	9.0	8.4	14.4	9.5
10.5	9.0	12.5	7.0	11.2	11.2	13.2	8.0	12.8	12.8
9.1	8.5	9.4	6.3	12.6	9.3	10.1	7.3	13.6	10.0
11.2	7.0	13.0	8.0	13.6	8.2	13.8	9.0	14.0	9.6
9.8	8.5	8.5	9.2	11.5	9.5	9.1	9.5	12.7	10.3
9.4	9.5	11.4	8.2	12.2	10.2	12.0	8.8	11.0	11.6
6.6	8.6	7.0	6.4	8.0	9.5	8.2	7.0	10.0	9.8
8.0	8.5	11.5	8.0	9.6	8.2	12.4	8.2	11.9	9.0
12.6	9.2	10.5	7.9	14.0	10.7	11.5	8.3	15.2	11.4
11.6	8.0	11.5	6.4	12.2	8.4	12.5	7.6	13.5	9.3
10.4	9.5	12.3	6.0	11.5	9.9	12.8	7.3	12.8	10.7
10.0	8.1	10.0	8.1	11.2	8.7	10.6	8.5	14.0	11.3
11.0	8.0	8.2	8.9	11.2	10.2	9.8	7.5	12.0	11.6
12.0	9.0	11.0	5.0	12.8	10.5	12.0	7.2	13.2	12.0
12.0	9.5	8.5	8.0	13.6	10.3	9.4	8.9	14.2	12.5
13.0	10.0	7.5	6.0	14.0	11.2	8.3	6.8	15.3	12.8
9.0	9.0	7.5	9.3	11.0	10.5	8.5	11.2	13.1	11.9
10.36	8.74	9.95	7.26	11.88	9.72	10.84	8.18	13.20	10.83

Table VI. (Continued)

128th		143rd				158th			
Low		High		Low		High		Low	
Long	Short	Long	Short	Long	Short	Long	Short	Long	Short
11.6	10.6	16.0	10.8	12.6	11.0	18.2	11.6	13.5	12.0
11.2	11.0	14.0	11.5	12.5	11.8	16.2	12.6	13.5	12.6
13.2	10.0	14.0	11.2	14.4	11.0	15.3	12.0	15.0	12.2
11.2	10.3	15.8	10.4	12.0	11.2	16.3	11.5	13.0	12.3
14.6	10.0	13.0	12.0	15.6	11.0	14.0	12.9	16.1	11.9
11.6	9.0	14.7	11.6	12.8	10.0	15.5	12.6	13.6	11.0
14.6	11.1	15.0	10.5	15.2	11.9	16.0	11.6	16.1	12.5
11.0	11.8	13.0	11.2	11.9	12.6	14.0	12.4	12.6	13.0
13.2	10.5	12.3	12.4	14.4	11.3	13.4	13.5	15.0	11.8
9.3	8.0	12.0	11.0	10.5	9.0	13.0	12.0	11.5	10.0
13.5	9.5	11.8	10.1	14.5	10.2	12.6	12.2	15.2	11.0
12.5	10.0	16.0	12.0	13.6	11.0	17.6	12.6	15.3	11.8
13.7	8.4	14.0	11.5	14.5	9.3	15.0	12.0	15.0	10.2
13.4	8.2	13.4	11.2	13.8	9.0	14.8	12.6	14.6	10.0
11.2	9.8	14.8	12.4	12.2	10.6	15.9	13.7	13.2	11.2
10.2	8.8	13.0	12.4	11.4	9.5	13.6	14.0	12.0	10.3
13.0	8.5	13.8	12.9	13.5	9.0	14.6	13.8	14.7	9.7
10.2	9.7	15.0	13.3	11.5	10.7	16.2	14.8	12.4	11.5
9.4	7.0	16.1	13.0	10.4	8.0	18.4	14.5	12.0	9.0
9.5	12.0	14.0	12.7	11.5	12.5	15.3	13.5	12.5	13.0
12.05	10.21	14.08	11.55	13.00	11.08	15.28	12.86	13.84	11.30

Table VII. Influence of Temperature and Daylength on Height Development of Plants (data in cm.)

Days after seeding	98th				113th			
Temperature	High		Low		High		Low	
Daylength	Long	Short	Long	Short	Long	Short	Long	Short
Data of height on plants	7.5	2.5	3.5	2.0	9.0	3.0	6.0	2.5
	9.5	2.0	3.0	2.2	10.0	2.9	4.2	3.0
	4.0	2.5	2.5	2.6	6.5	3.0	5.4	3.0
	6.0	2.4	2.5	2.6	7.2	3.2	5.0	2.8
	7.5	2.6	2.6	2.0	8.5	3.6	5.2	2.6
	10.5	3.2	3.2	2.0	12.4	3.4	5.6	2.5
	8.4	2.7	3.7	2.0	9.5	3.5	4.6	2.4
	7.2	3.0	3.0	2.0	8.5	4.0	6.4	2.5
	8.0	2.5	3.5	3.5	9.0	3.0	4.5	4.8
	4.8	2.6	3.5	2.5	6.5	4.2	5.0	3.0
	6.5	1.6	3.6	3.5	7.0	3.2	4.3	3.8
	10.5	2.8	3.5	2.5	11.5	3.5	4.6	3.2
	7.4	2.4	2.6	2.3	8.4	2.4	3.2	2.8
	7.8	3.0	2.8	2.6	9.5	3.5	3.8	3.0
	6.0	2.2	2.4	2.8	6.5	3.1	3.6	3.5
	8.0	3.0	4.5	2.5	9.5	3.5	5.0	3.0
	7.5	2.3	3.2	1.5	8.0	2.9	3.7	1.8
	10.0	3.5	3.0	3.6	10.8	4.0	5.5	4.0
	8.0	3.3	3.3	2.3	9.0	3.8	5.8	3.2
	8.6	4.0	3.5	2.0	9.6	4.5	4.0	2.5
Average	7.68	2.20	3.15	2.45	8.84	3.41	4.77	2.99

Table VII. (Continued)

128th				143rd			
High		Low		High		Low	
Long	Short	Long	Short	Long	Short	Long	Short
10.0	4.0	9.0	3.2	12.2	4.5	10.5	4.0
11.5	4.0	7.0	3.5	14.5	4.5	8.2	4.4
8.0	4.5	7.0	3.5	8.5	5.2	8.4	4.5
11.5	4.0	7.5	3.4	12.8	4.0	9.6	4.6
9.6	4.4	7.5	3.6	10.6	5.6	8.0	4.0
13.2	4.2	7.2	2.8	14.6	4.8	8.0	3.5
10.3	4.5	5.3	3.0	12.0	5.0	6.8	3.8
9.5	4.6	7.0	3.0	11.5	5.6	9.6	3.0
9.8	4.0	5.5	5.6	10.8	4.8	6.5	6.4
7.4	4.8	7.0	3.6	8.4	5.0	8.0	4.0
8.0	4.0	5.5	4.6	9.0	5.6	6.5	5.2
13.0	4.0	7.0	4.2	18.0	5.5	7.8	4.7
9.6	3.8	5.2	4.0	10.6	4.4	6.0	4.8
10.8	4.2	4.8	3.7	11.8	4.6	5.6	4.2
8.2	3.5	5.8	4.2	9.4	4.0	6.2	4.8
10.5	4.4	7.5	3.8	11.5	4.8	8.0	4.2
9.5	3.6	4.9	2.5	10.6	4.0	5.5	3.0
11.6	4.6	6.0	4.6	12.8	5.0	6.5	5.0
10.2	4.3	6.4	4.0	11.4	4.8	7.0	4.4
10.4	5.2	5.2	3.0	10.5	5.6	6.3	3.6
10.13	4.23	6.41	3.69	12.58	4.88	7.45	4.45

Table VII. (Continued)

158th			
High		Low	
Long	Short	Long	Short
13.8	6.2	12.5	4.5
15.5	5.4	10.0	8.0
11.5	7.6	9.6	6.2
13.5	5.3	10.0	5.0
11.6	6.2	9.8	5.0
16.3	5.8	10.0	4.0
13.4	6.3	7.4	5.2
12.5	8.4	10.6	4.3
12.0	7.8	7.8	7.4
9.6	9.4	9.2	5.5
10.0	7.8	7.5	6.2
20.2	6.2	9.0	6.0
11.8	5.8	8.4	6.0
13.4	6.0	6.5	5.5
10.6	6.2	6.8	5.5
13.5	7.2	9.4	5.6
11.4	6.8	6.0	4.2
13.3	7.6	8.0	5.8
12.6	5.8	7.8	5.6
16.0	6.4	7.5	7.1
13.12	6.71	8.69	5.63

Flower Initiation and Development

Figure IX B to D shows the early stages of flower bud development: B, bud beginning to differentiate as a specialized form; C, bud beginning to develop into three parts; D, a bud differentiated into its component parts; A, a cross section of development of buds and their locations. Miscroscopic observations of the sections of the tips of 68-day old plants (Fig. IX B) showed the initiation of flower buds had taken place in "long day" plants but not in "short day" plants. Apparently additional periods of light had speeded up initiation of flower buds so that they were visible within 68 days after seeding. Under "short day" conditions, flower buds differentiated between 68 and 83 days at the "high temperature" and between 68 and 98 days at the "low temperature". Therefore, while temperature effect had little influence on the initiating time under long days, high temperature speeded up the initiation under short days at least 15 days. It is not correct, however, to assume that temperature can be used by itself to grow successful flowers because of the day length response to vegetative growth.

From the data compiled in Table VIII we might conclude that plants with additional light were budding 15 days earlier at "high temperature long day" than the "high temperature short day", 25 days earlier at "low temperature long day" than "low temperature short day", and were flowering 14 days earlier at "high temperature long day" than the "high temperature short day", 27 days earlier at "low temperature long day" than at "low temperature short day".

Relation between bud initiation, budding, and flowering can be seen on Table VIII. Plants with additional light at high or low temperatures took about 82 days to show buds after bud initiation, and about 15 more days to form flowers. Plants without additional light required about 82 days from initiation to budding in a high temperature but only 78 days in a low temperature. This was probably the result of the increased length of time required to initiate the buds at the low temperature. From budding time to flowering showed very slight differences under any treatment.

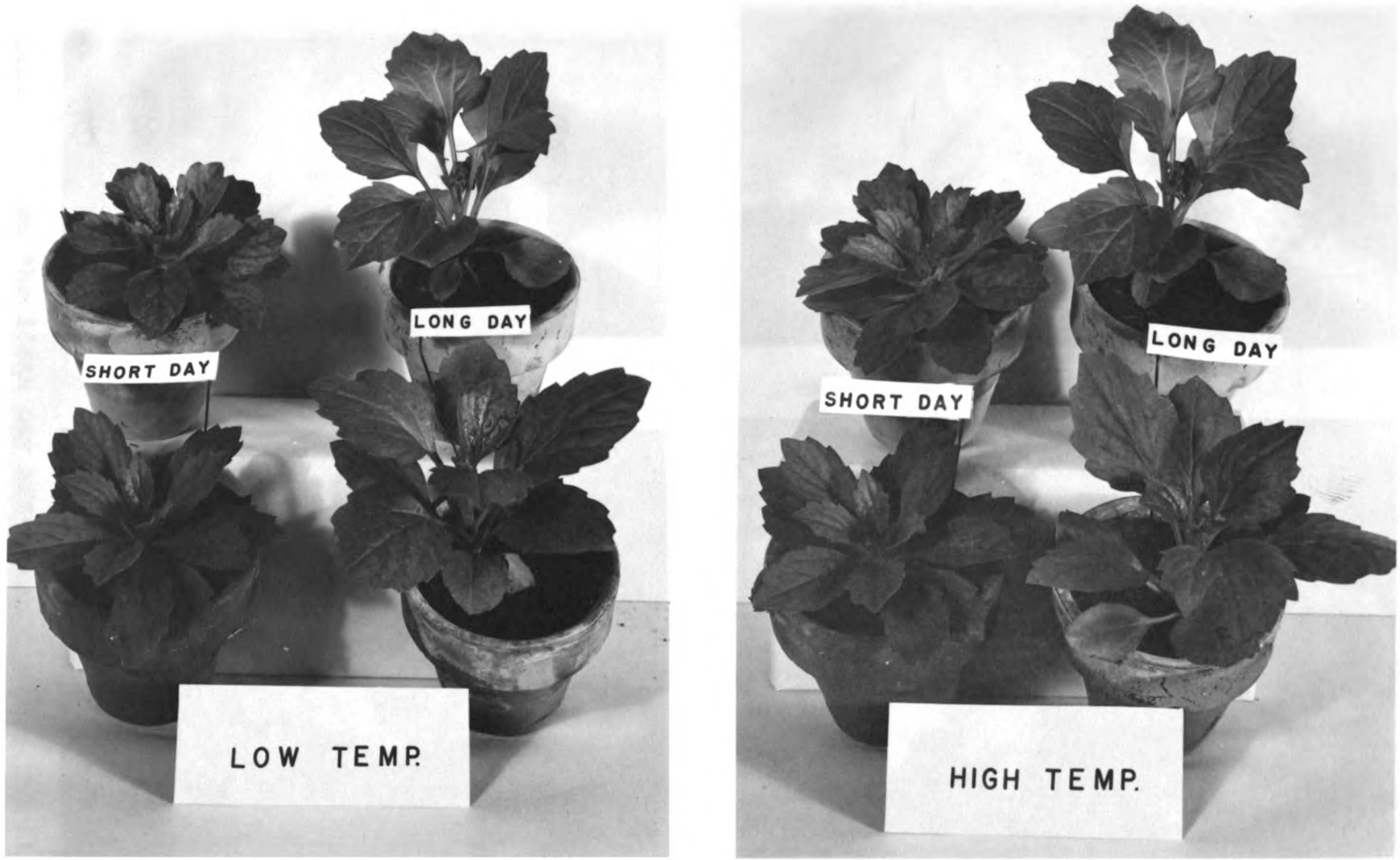


Fig. VII.--Taken on the 83rd day after seed sowing. (January 21, 1949)

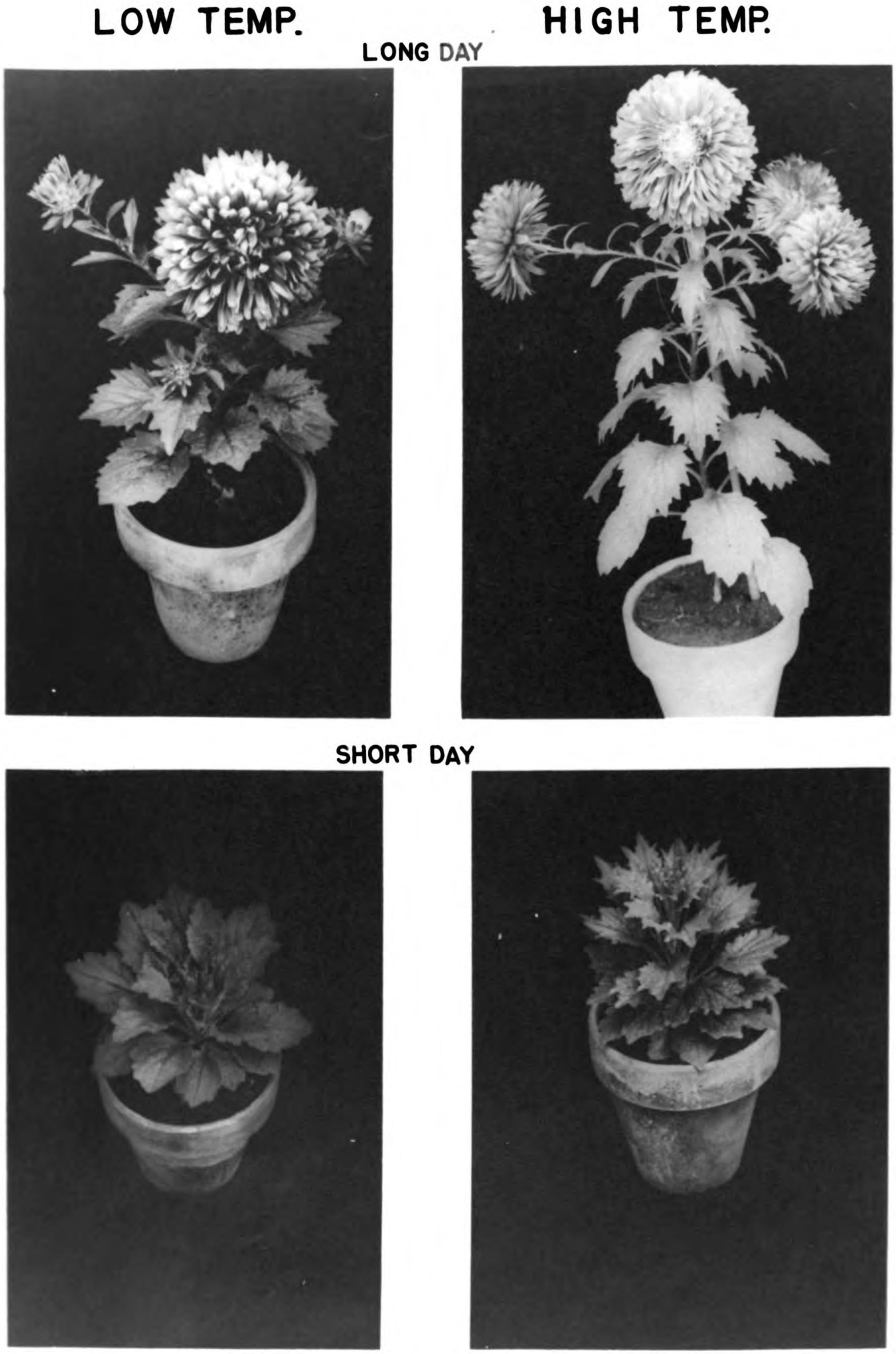


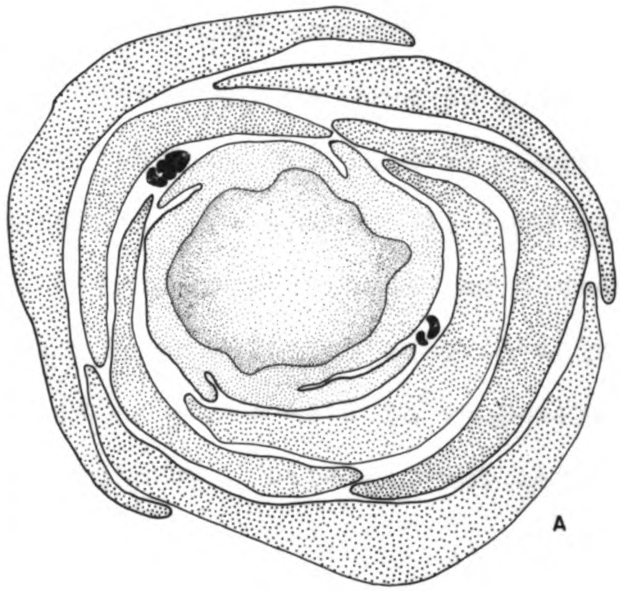
Fig. VIII.-Taken on the 158th day after seed sowing. (April 15, 1940)

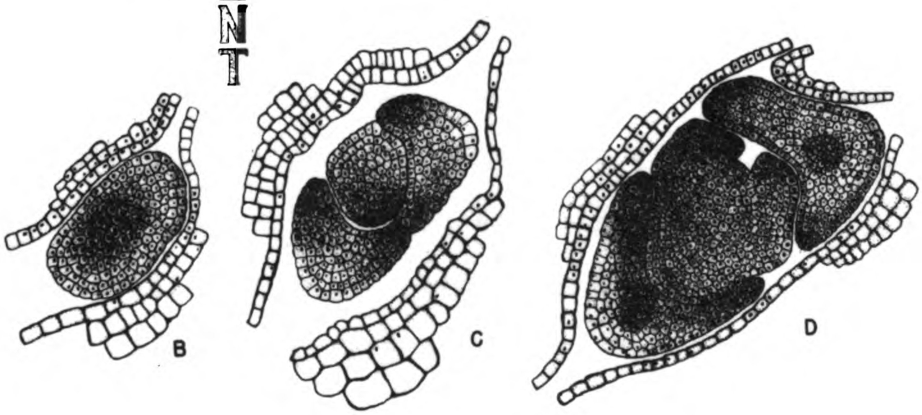
Table VIII. Effect of Daylength and Temperature on Bud Initiation, Bud Appearance, and Flower Appearance.

Treatment		Time in days after seeding: Bud initiation	Bud appearance	Flower appearance	Initiation to budding	Budding to Flowering
High temperature	Long day	68	150	165	82	15
	Short day	83	165	179	82	14
Low temperature	Long day	68	151	165	83	14
	Short day	98	176	192	78	16

Fig. II.

EARLY STAGES OF FLOWER DEVELOPMENT





Recommendations

The China aster is recommended for culture as a pot plant for spring. Seeds should be sown in early October in a sandy loam soil. The optimum temperature for seed germination is about 65° F. Seeds may be sown in rows or scattered uniformly in flats or benches, but in most cases it seems best to sow them in rows two inches apart. As soon as two true leaves have formed, the seedlings should be potted. After three months they should be repotted into five-inch pots.

The China aster grows well in temperatures of 55° to 60° F. or a little higher. Liberal ventilation should be provided.

The plants require much moisture, but the water must be applied with care. Watering in early forenoon seems to give most satisfactory results. At no time during their growth should the plants be allowed to become dry.

A naturally deep, well drained, friable soil with readily available plant food is recommended.

Artificial light supplied by 60-watt, 120-volt lamps, started in early November, generally is advisable. The light should be turned on daily for a period of at least five hours after sunset until the buds are well formed. The artificial lighting of seedlings preparatory to planting has resulted in earlier flowering. The different varieties react somewhat differently to artificial lighting. Therefore, it is difficult to predict the exact degree of success that may be obtained by using artificial light on any particular variety.

Summary

1. Seeds of the variety Sensation were sown on October 30, 1948, at a temperature of 65° F. After 37 days, the seedlings were divided into two groups, one of which was maintained at "low" (50° F.) temperature and one at "high" (65° F.) temperature, and each group divided into two groups subjected to long day and short day light treatments using 60-watt, 120-volt lamps to extend the daylight period with artificial light for five hours after sunset every day until March 31, 1949 for the long day plants. Records were kept of (a) diameter and height of plants at 15-day intervals, and (b) the time of appearance of first buds and first full bloom on each plant until there was a total of approximately 50 buds or flowers for each group of 20 plants. Collections of leaves and young leaves at center axis elongation were also made every 15 days; all collection materials for the entire study were made into permanent slides.
2. Artificial light supplementing daylight for five hours resulted in budding two weeks earlier and flowering 12 days earlier at "high temperature" than occurred without supplementary light. Budding 25 days earlier and flowering 27 days earlier at "low temperature" was obtained by the use of supplementary light to lengthen the day.

3. Floral initiation and development was found to occur sooner in plants that were exposed to a "high temperature, long day" environment compared to those exposed to a "high temperature, short day" sequence. Similarly, floral initiation and development was found to occur in "low temperature, long day" plants at about the same time that it occurred under "high temperature, long day" treatment.

Literature Cited

1. Bailey, L. H. Some preliminary studies of the influence of the electric arc lamp upon greenhouse plants. Cornell Univ. Agr. Exp. Sta. Bull., 30, 83-122. 1891.

2. Bailey, L. H. The Standard Cyclopedia of Horticulture. The Macmillan Co., New York, Vol. I, 630-631. 1947.

3. Biebel, Joseph. Temperature, photoperiod, flowering and morphology in cosmos and China aster. Proc. Am. So . Hort. Sci., 34, 635-643. 1936.

4. Biebel, J. P., Greene, Laurenz, and Withrow, R. B. Flowering response to temperature in China aster. Proc. Am. Soc. Hort. Sci., 33, 645-646. 1935.

5. Garner, W. W., and Allard, H. A. Effect of the relative length of day and night and other factors of the environment on growth and reproduction in plants. J. Agr. Res., 18, 553-606. 1920.

6. Garner, W. W., and Allard, H. A. Effect of abnormally long and short alternations of light and darkness on growth and development of plants. J. Agr. Res., 43, 629-652. 1913.

7. Greene, Laurenz, Withrow, Robert B., and Richman, Milfred W. The response of greenhouse crops to electric light supplementing daylight. Purdue Univ. Agr. Exp. Sta. Bull., 366, 1-20. 1932.

8. Harvey, R. B. Growth of plants in artificial light. Bot. Gaz., 74, 447-451. 1922.

9. Honeywell, E. R. Aster culture. Purdue Univ. Agr. Exp. Sta. Cir., 200, 1-23. 1941.

10. Kellerman, K. F. A review of the discovery of photoperiodism: The influence of the length of daily light periods upon the growth of plants. Quarterly Rev. of Biol., 1, 87-94. 1926.

11. Laurie, Alex, and Chadwick, L. C. Commercial Flower Forcing. P. Blakiston's Son and Co., Inc. Philadelphia, Pa. 1943.

12. Laurie, Alex, and Poesch, G. H. Photoperiodism--The value of supplementary illumination and reduction of light on flowering plants in the greenhouse. Ohio Agr. Exp. Sta. Bull., 513, 1-42. 1932.

13. Poesch, G. H., and Laurie, Alex. The use of artificial light and reduction of the daylight period for flowering plants in the greenhouse. Ohio Agr. Exp. Sta. Bull., 559, 1-43. 1935.

14. Post, Kenneth. The effects of day length and light intensity on vegetative growth and flowering of the China aster (*Callistephus chinensis*). Proc. Am. Soc. Hort. Sci., 30, (1934), 626-630. 1935a.

15. Post, Kenneth. Producing early China asters. Florists Exch. and Hort. Trade World, April 18, 1936, p. 19. 1936b.

16. Post, Kenneth. Effects of daylength and temperature on growth and flowering of some florist crops. Cornell Univ. Agr. Exp. Sta. Bull., 787, 17-19. 1942.

17. Post, Kenneth, and Mixon, M. W. A graphic light meter. Agr. Engin., 21, 429-430. 1940.

18. Post, Kenneth. Florist Crop Production and Marketing. Orange Judd Publishing Co., Inc. N. Y. 1949.

19. Richman, M. W. Aster seedlings given additional light bloom quicker. Florists Rev., Feb. 16, 1933.

20. Stone, George E. The relation of light to greenhouse culture. Mass. Agr. Exp. Sta. Bull., 144, 1-39. 1913.

21. Withrow, R. B. Artificial lighting for forcing greenhouse crops. Purdue Univ. Agr. Exp. Sta. S. B., 533, 1-27. 1948.

22. Withrow, R. B., and Benedict, H. M. Photoperiodic responses of certain greenhouse annuals as influenced by intensity and wavelength of artificial light used to lengthen the daylight period. Plant Physiol., 11, 225-249. 1936.

23. Withrow, R. B. Plant forcing with electric lights. Ind. Agr. Exp. Sta. Circ., 206, 1-13. 1934.