THE INFLUENCE OF DAYLENGTH AND TEMPERATURE UPON THE FLOWERING OF VIOLA ODORATA

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This is to certify that the

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THE INFLUENCE OF DAYLENGTH AND TEMPERATURE

UPON THE FLOWERING OF *VIOLA ODORATA*

By

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INTRODUCTION

The production of violets (Viola odorata) as a commercial greenhouse crop has become less common in the central and eastern United States during the last thirty years because of the difficulties encountered in timing the crop to coincide with the demand. When Easter and Mother's Day have occurred late in the spring, flowers have been of a poor quality and production has almost ceased.

The violet produces the attractive chasmogamous flowers when the plants are exposed to a short daylength for an extended period of time. Inconspicuous cleistogamous flowers are formed when the plants are exposed to a long photoperiod. Consequently, shortening the photoperiod could logically extend the period of commercial flower production into the more desirable spring months.

Viola odorata is not unique in its growth response to changes of photoperiod. A large number of the plants that respond to photoperiod give very unlike responses at different temperatures. For example, Roberts and Struckmeyer (1939) studied the influence of temperature on the response of a large number of plants to photoperiod. They found that *Antirrhinum majus* and *Petunia hybrida* would flower only under long days at a temperature above 65° F. If the temperature were lowered to 55° F., however, these species would flower under any daylength. High temperatures have been used to produce the same effect as long days for the purpose of inducing formation of flowers on *Rudbeckia bicolor* (Murneek, 1940).

Suggestions by Post (1949) as well as results by Murneek (1940), Roberts and Struckmeyer (1939), Madge (1929) and others, stimulated a desire to investigate the influence of temperature on the response of *Viola odorata* to photoperiod. In addition, it was desired to study the length of time required for chasmogamous and cleistogamous flowers to appear after the beginning of a favorable photoperiod. This might be of considerable value to commercial greenhouse operators.

REVIEW OF LITERATURE

History. It has been known for many years that plants of the genus *Viola* produce chasmogamous and cleistogamous flowers. Muller first made this observation in 1857 and at that time described the cleistogamous flowers of six species (Madge, 1929).

Influence of Light Intensity. Most of the work which has been done with the influence of light intensity on the growth of *Viola* has been with reference to its affect on flowering. It has been stated however that the plants of *Viola* grow best under a maximum light intensity of 1200 foot candles (Post, 1949).

An attempt to prolong the production of chasmogamous flowers of *Viola odorata* was reported by Bradley (1901). He could prolong flowering two or three weeks by reducing the light intensity during the last week in February. Madge (1929), however, found no difference in the period during which chasmogamous flowers were produced in the shaded and the sunny outdoor plots. She did obtain relatively more chasmogamous flowers from the shaded plots and also more cleistogamous flowers on the plants that were grown in full sunlight.

Influence of Photoperiod. The flowering habit of Viola has been described as being indeterminate, by Allard and Garner (1940), with the completeness of the flower produced depending upon the length of the photoperiod.

The first extensive research concerning the affect of length of day upon the flowering of many species of plants by Garner and Allard (1920) included Viola fimbriatula. They found that when plants of Viola fimbriatula var. J. E. Smith were exposed to 7 hours of light followed by 17 hours of darkness, they produced purple chasmogamous flowers in one month. A few cleistogamous flowers were also produced by this treatment. Plants exposed to a normal daylength in June and July at Beltsville, Maryland, produced numerous cleistogamous flowers, but no chasmogamous flowers.

In later work both Viola fimbriatula var. J. E. Smith and Viola papilionacea var. Pursh were observed to produce chasmogamous flowers under a daylength of 10 to 12 hours. In addition, long days tended to increase the plant vigor and to cause the formation of excessively large leaf blades, long petioles, and cleistogamy; while short days tended to cause the development of small, short petioled leaves and chasmogamous flowers (Allard and Garner, 1940).

Similar results have been obtained by other investigators. Madge (1929) found, that at Royal Halloway College in England, Viola odorata produced chasmogamous

flowers between September and March and cleistogamous flowers between May and September. In 1932 Bergdolt observed that cleistogamous flowers were produced under conditions favoring large amounts of vegetative growth and also that the production of chasmogamous flowers was favored by a reduction in foliage either by surgical or nutritional means. It was believed that the most important factors having a definite influence on the morphology and physiology of Viola odorata were a combination of light, moisture, and nutrition (Bergdolt, 1932).

Influence of Temperature. Viola hirta and Viola sylvestris produced cleistogamous flowers under a photoperiod of 16 hours, if the temperature permitted what was termed by Chaurod (1947) as "active growth". He obtained no chasmogamous flowering in these two species under a photoperiod of eight hours duration and a temperature of 53° to 59° F. from October to May. A few pale colored flowers were produced during April under the eight hour photoperiod and natural outdoor temperatures. He concluded that chasmogamous flowers were produced by these two varieties under short days only if there was a "rhythm of warmth and cold in the temperature". This did not appear to refer to diurnal temperature fluctuations, but to changes over a longer period of time.

Morphology. Madge (1929) catalogued the flowers produced by Viola odorata var. praecox into three types: cleistogamous, semi-cleistogamous, and chasmogamous. She found that the semi-cleistogamous flowers, an intermediate type showing several stages of transition between the two extremes, was produced during a short period in the spring and fall. The semi-cleistogamous flowers resembled the cleistogamous flowers in the complete absence of a spur and nectary and would be classified as a cleistogamous flower by a taxonomist recognizing only two types of flowers.

Chasmogamous and cleistogamous flowers undergo the same stages early in their development. The ovules, however, differentiate earlier in the cleistogamous flower. The cleistogamous flowers appear incomplete in their development, but the flower structures in these flowers resemble those in the chasmogamous blooms in number and arrangement of parts. Many of the structures in the cleistogamous flowers remain in an undeveloped stage and only those parts essential for the protection of the reproductive organs and for seed production are fully developed (Theron, 1939).

Descriptive Morphology. In order to clarify the following description of the flower types, four diagrams of the flowers of Viola odorata are presented in Figure 1.

In the cleistogamous flower, A, there are five normal

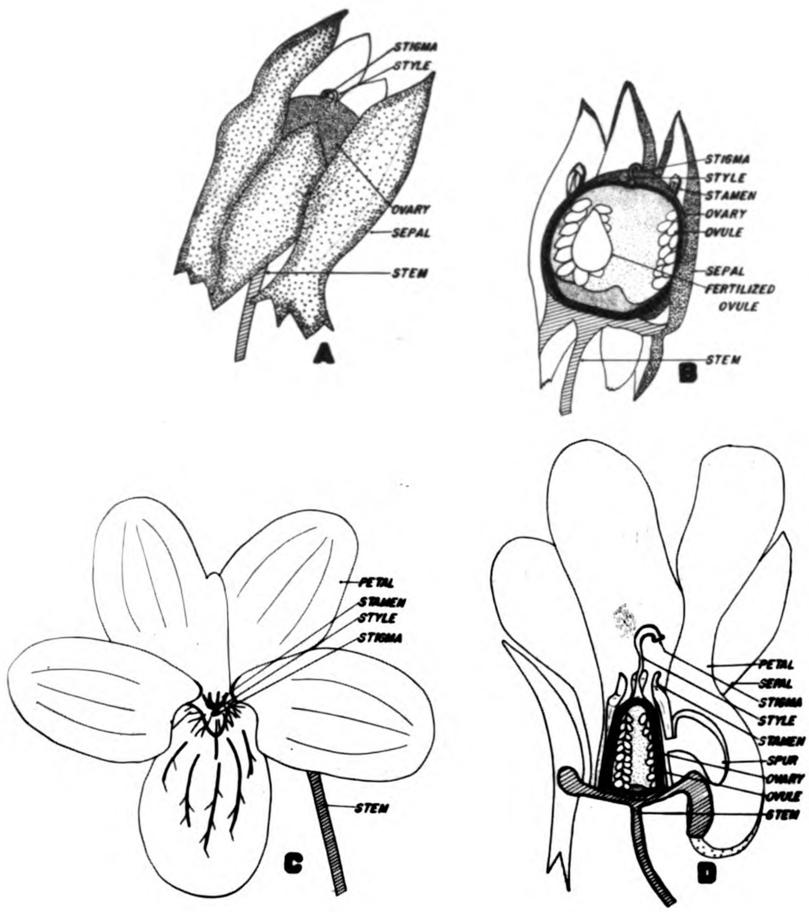

Fig. 1. Diagramatic drawings of the flower types of Viola odorata. A. a mature cleistogamous flower; B. a longitudinal section of a cleistogamous flower; C. a mature chasmogamous flower; D. a longitudinal section of a chasmogamous flower.

sepals which enclose the flower and show no signs of opening until the fruit is formed. The cleistogamous flower, A, is illustrated with the fruit fully formed and the tips of the sepals spread apart making the ovary visible. The petals, when present, are 2 to 5 in number and take the form of small membranous strap shaped, almost entirely unpigmented structures. The corolla may be entirely missing as in B. The androecium consists of five stamens which serve in self pollination of the flower as shown in B, Figure 1. The gynoecium is made up of a normal ovary, containing three carpels with three parietal placentae, and a modified style and stigma. The style is bent over to form a hook, thus bringing the stigmatic surface closer to the pollen sac of the two anterior stamens. The bent style is shown in B, Figure 1, but the stigmatic surface does not appear to be near the pollen sacs of the stamens because of the maturity of the flower illustrated (Descriptions after Goroczynski, 1932; Weste, 1931; Theron, 1939).

In the chasmogamous flower will be found five free petals, C, Figure 1, alternating with five free sepals (not shown). The anterior petal contains a long hollow spur acting as a protective sheath for the nectary spurs and as a storage reservoir for the nectar. In the reproductive part of the flower are five free stamens. Two stamens are inside the anterior petal and have the nectary spurs attached. One of the stamens shown in D, right, is

inside the anterior petal and the nectary spur is attached to it. The ovary is made up of three carpels and has three parietal placentae. Two of the placentae are shown in D, Figure 1, with abortive seeds attached (Description after Madge, 1929).

One fertilized ovule is found in the ovary of the cleistogamous flower B, in contrast to an absence of fertilization in the ovary of the chasmogamous flower D, Figure 1. This is typical of Viola odorata in which only the cleistogamous flowers produce seed. In a few species such as Viola riviniana, as a result of variations in the structure of the androecium and gynoecium, both flower types produce seed (Description after Weste, 1931).

PROCEDURE

On October 15, 1950, one hundred seventy-five young plants of *Viola odorata* var. Fries Favorite were planted in a sterilized soil (50 per cent peat and 50 per cent sandy loam) in four inch pots. The plants were placed in the plant science greenhouse at Michigan State College under a 50 degrees Fahrenheit night temperature (50° F.N.T.). After 3 weeks, four groups of 43 plants per group were selected for uniformity among the groups. Two groups were grown in one greenhouse with a 40° F.N.T. and the other two were grown in another greenhouse at 50° F.N.T. In each of these two houses one group was supplied with a 16, and the other group with an 8 hour period of light. The resultant treatments were:

I. 40° F.N.T., 16 hr. photoperiod

II. 40° F.N.T., 8 hr. photoperiod

III. 50° F.N.T., 16 hr. photoperiod

IV. 50° F.N.T., 8 hr. photoperiod

The temperature was controlled in all treatments by automatic thermostats. In groups I and II, automatically controlled ventilators enabled accurate control of temperature. In treatments III and IV it was necessary to use slightly less accurate manually operated ventilators.

The long light period in treatments I and III was kept constantly at 16 hours. Natural day length was extended by the use of incandescent lights giving a light intensity of approximately 15 to 25 foot candles at the leaf surface. The 8 hour photoperiod was obtained in treatment II by the use of a covering of black sateen cloth and in treatment IV by moving the plants into a connecting dark room kept at the same temperature as the greenhouse.

Soil tests were made every two weeks. A balanced complete soluble fertilizer was applied in solution as needed to attempt to maintain the nutrients at the following levels: nitrogen, 20 to 30 ppm. spurway; phosphorus, 5 ppm. spurway; potassium, 10 ppm. spurway. The pH of the soil was from 5.5 to 6.5.

On December 7, 1950, four weeks after the treatments were begun, all of the flower buds visible on the plants were removed, assuming that these buds had been initiated before the controlled conditions were supplied. On January 6, 1951 (four weeks later) and at regular weekly intervals thereafter, all of the flowers were cut and a record was made of the number of the chasmogamous flowers produced. A record was also made of the peduncle length and the diameter of the flowers in inches from the tips of the opposite petals adjacent to the anterior petal.

On February 9, 1951, 13 weeks after the treatments were begun, ten plants were selected at random from each

TABLE I

MEAN WEEKLY TEMPERATURES FOR 40° AND 50° FAHRENHEIT NIGHT TEMPERATURE (F.N.T.) HOUSES

Week	40° F.N.T.		50° F.N.T.	
	night	day	night	day
14	41	47	52	59
15	42	50	52	60
16	42	53	54	62
17	41	49	52	61
18	44	55	53	66
19	45	61	56	67
20	49	56	54	61
21	45	63	54	67
22	42	50	50	58
23	44	58	51	64
24	54	76	59	77
25	53	72	59	76

treatment. These groups of ten plants each were moved to the opposite photoperiod at the same temperature at which they had been growing and records were continued as previously with the addition of the four new groups. Therefore, after February 9th there were the following eight groups of plants under observation:

I .	40° F.N.T.,	16 hr. photoperiod	33 plants
IA.	40° F.N.T.,	16 hr. photoperiod	10 plants
		previously 8 hr. photoperiod	
II .	40° F.N.T.,	8 hr. photoperiod	33 plants
IIA.	40° F.N.T.,	8 hr. photoperiod	10 plants
		previously 16 hr. photoperiod	
III .	50° F.N.T.,	16 hr. photoperiod	33 plants
IIIA.	50° F.N.T.,	16 hr. photoperiod	10 plants
		previously 8 hr. photoperiod	
IV .	50° F.N.T.,	8 hr. photoperiod	33 plants
IVA.	50° F.N.T.,	8 hr. photoperiod	10 plants
		previously 16 hr. photoperiod	

All plants were transferred to 6 inch pots on March 17, where they remained until the end of the experiment. On May 8, 1951, 25 weeks after the original treatments were begun the experiment was discontinued because it was difficult to maintain 40 and 50° F.N.T. (Table I). Leaf area of ten plants from each group was measured with a planimeter to compare the vegetative growth in each treatment.

To get an indication of how long the plants could be

kept flowering in the spring of the year, twenty plants were retained after May 8th under an eight hour daylength. The temperature during this period rose considerably above the 50° F.N.T.

Fig. 2. Violet plants after exposure to 17 weeks of long or short days in the greenhouse at 50° F. night temperature.

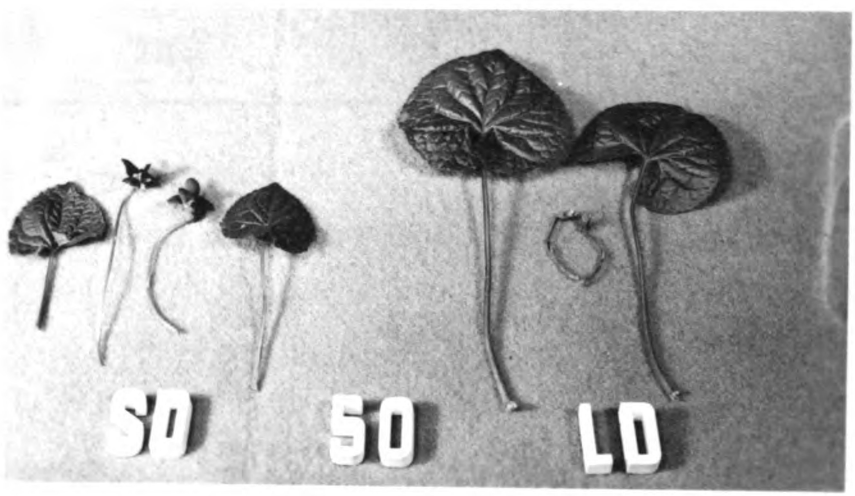

Fig. 3. Violet leaves and flowers showing the relative size after 25 weeks of long or short days in the greenhouse at 50° F. night temperature: Left, chasmogamous flowers and small leaves produced during short days; Right, cleistogamous flowers and large leaves produced during long days.

TABLE II

INFLUENCE OF TEMPERATURE AND PHOTOPERIOD
ON VEGETATIVE GROWTH

Treatment	Average number of leaves per plant	Average leaf area per plant in square inches	Average area per leaf in square inches
Long days for 25 weeks			
III 50°	61.8	421.8	7.0
I 40°	39.4	323.0	8.4
Short days for 25 weeks			
IV 50°	47.0	161.0	3.5
II 40°	41.8	184.7	4.5
L.S.D. .05	9.1	32.3	.8
L.S.D. .01	12.3	43.3	1.1
Short days for 13 weeks followed by long days for 12 weeks			
IIIA 50°	52.2	325.1	6.4
IA 40°	30.9	243.4	8.1
Long days for 13 weeks followed by short days for 12 weeks			
IVA 50°	51.7	228.4	4.5
IIA 40°	44.4	223.5	5.1

DISCUSSION OF RESULTS

Vegetative Growth

<u>Leaf Size</u>. Figure 2 is a photograph of a group of plants from the long and short photoperiodic treatments in the 50° F.N.T. 17 weeks after the treatments were initiated. The most obvious response of this species to a 16 hour photoperiod is the development of large leaf blades on long petioles, making a much more vigorous plant in contrast to the smaller leaves and shorter petioles produced on less vigorous plants grown under the short photoperiod of 8 hours. To further emphasize this difference separate leaves have been removed from plants in each treatment (Figure 3) after 25 weeks. The resultant plant growth was comparable to that found by Allard and Garner (1940).

A comparison of leaf areas after 25 weeks as influenced by both temperature and length of photoperiod is shown in Table II. The average total leaf area per plant in the long photoperiodic treatment at 50° F.N.T. was found to be 98.8 square inches greater than the average total leaf area per plant in the long photoperiod at 40° F.N.T. This was significant at the 1 per cent level. No significant difference at the 5 per cent level

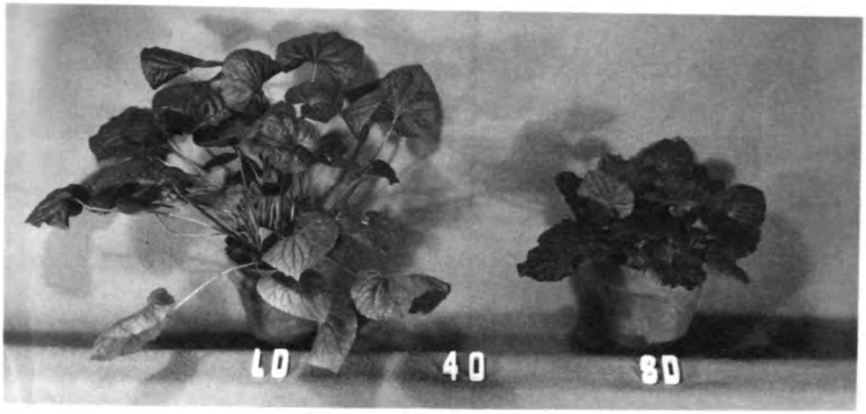

Fig. 4. Violet plants showing the relative size after 25 weeks of long or short days in a greenhouse at 40° F. night temperature.

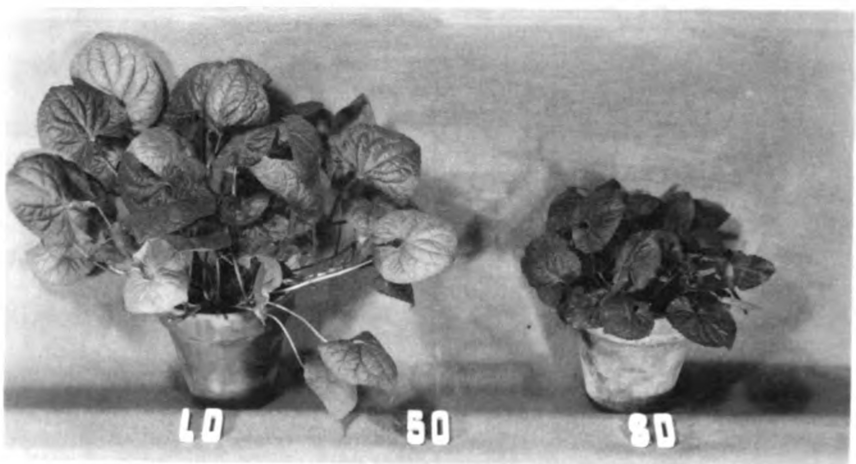

Fig. 5. Violet plants showing the relative size after 25 weeks of long or short days in a greenhouse at 50° F. night temperature.

was found between the average total leaf area per plant in the short photoperiod treatments in the 40 and 50° F.N.T. As would be expected from the data presented in Table II and Figures 4 and 5, highly significant differences (at the 1 per cent level) were found in the total leaf area per plant between the long and short photoperiod treatments for 25 weeks at the given temperatures. At the 50° F.N.T. there was a difference of 260.8 square inches, and a difference of 138.3 square inches at 40° F.N.T.

The leaves on the plants in the 40° F.N.T. and long days were found to be on the average 1.4 square inches larger than the leaves on the plants in the 50° F.N.T. long day treatment. Likewise the leaves on the plants in the short days at 40° F.N.T. were found to be on the average 1 square inch larger than the leaves on the plants in the 50° F.N.T. short day treatment. The differences between temperatures were significant at the 5 per cent level for the short day treatments and at the 1 per cent level for the long day treatments. This increase in leaf size is an indication that expansion of the blades was greater in the 40° than in the 50° F.N.T. In comparing the areas of individual leaves in the long and the short photoperiodic treatments, an average difference of 3.5 square inches was found in the leaf areas in the 50° F.N.T. groups while a difference of 3.9 square inches was found in the 40° F.N.T. groups. These differences were both significant was found between the average total leaf area per plant in the short photoperiod treatments in the 40 and 50° F.N.T. As would be expected from the data presented in Table II and Figures 4 and 5, highly significant differences (at the 1 per cent level) were found in the total leaf area per plant between the long and short photoperiod treatments for 25 weeks at the given temperatures. At the 50° F.N.T. there was a difference of 260.8 square inches, and a difference of 138.3 square inches at 40° F.N.T.

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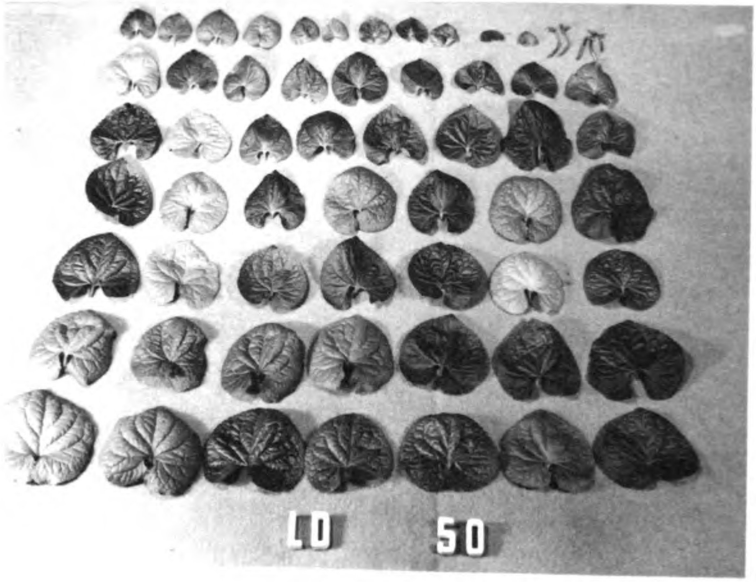

Fig. 6. Leaf blades and flowers from one violet plant after 25 weeks of long days in a greenhouse at 50° F. night temperature.

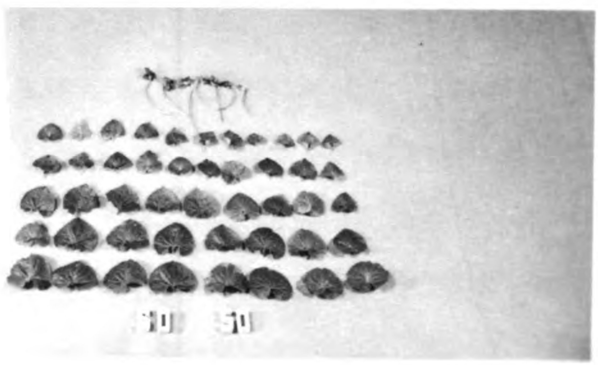

Fig. 7. Leaf blades and flowers from one violet plant after 25 weeks of short days in a greenhouse at 50° F. night temperature.

at the 1 per cent level (Table II).

To further illustrate the difference in leaf size in the different photoperiodic treatments, the leaves from one plant in the 50° F.N.T., long photoperiodic treatment are shown in Figure 6. The contrast in size of these leaves compared to the leaves from a plant grown in the short photoperiod at 50° F.N.T. (Figure 7) is quite apparent.

Leaf Number. An average of 22.4 more leaves were found on plants grown in the long photoperiod, 50° F.N.T. than were found on those grown in the long photoperiod at 40° F.N.T. This difference was significant at the 1 per cent level. No significant difference at the 5 per cent level was found in leaf number between the short photoperiodic treatments at the given temperatures (Table II).

Comparing the influence of photoperiod on the number of leaves, it was found that a significantly greater number of leaves per plant (at the 1 per cent level) were produced under the long photoperiod, than under the short photoperiod, 50° F.N.T. (Figures 6 and 7). The actual difference amounted to an average of 14.8 leaves. No significant difference at the 5 per cent level was found in the number of leaves produced per plant in the long and short photoperiods at 40° F.N.T. (Table II).

Stoloniferous Growth. There was no development of stolons at either temperature in the short photoperiod.

Although no actual measurements were made it was quite apparent that stoloniferous growth was more rapid in the 50° than in the 40° F.N.T. in the long photoperiod.

General Influence of Temperature and Photoperiod. The generally high significant differences in the vegetative growth, found between the long and the short photoperiodic treatments at both temperatures (Table II) shows that the vegetative growth is more rapid in the long than in the short photoperiod. The less vigorous growth in the short photoperiod is further exemplified by the insignificant differences, at the 5 per cent level, in the vegetative growth produced under the 8 hour photoperiod at the 40 and the 50° F.N.T. The significant increase in growth under the long photoperiod in 50 compared to 40° F.N.T. serves to show that also the higher temperature tends to produce more vegetative growth of *Viola odorata*. Likewise it follows that the lower temperature tends to produce less vegetative growth of this species.

It is important to note that although both the low temperature and the short photoperiod used in this experiment reduced vegetative growth, the differences in temperature did not influence the growth as much as the differences in the photoperiods used (Figures 4 and 5).

Influence of Photoperiodic Change. Photographs (Figures 8 and 9) illustrate plants which were grown at

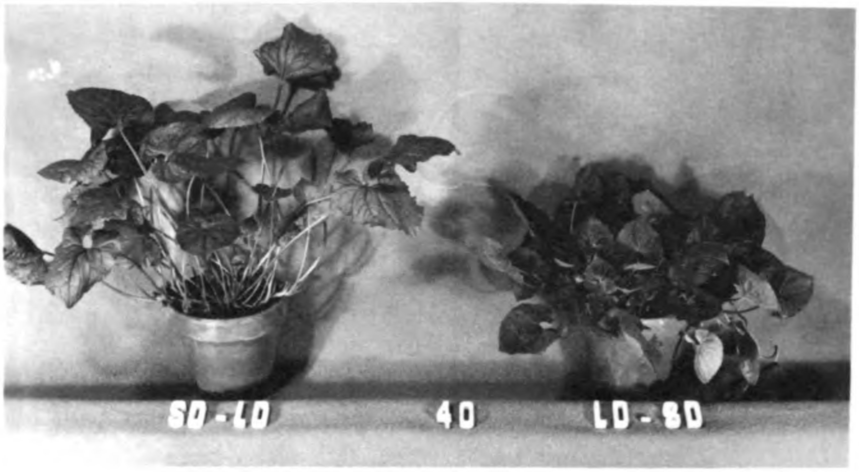

Fig. 8. Violet plants grown at 40° F. night temperature: Left, exposed to short days for 13 weeks followed by long days for 12 weeks; Right, exposed to long days for 13 weeks followed by short days for 12 weeks; All plants grown concurrently in a greenhouse.

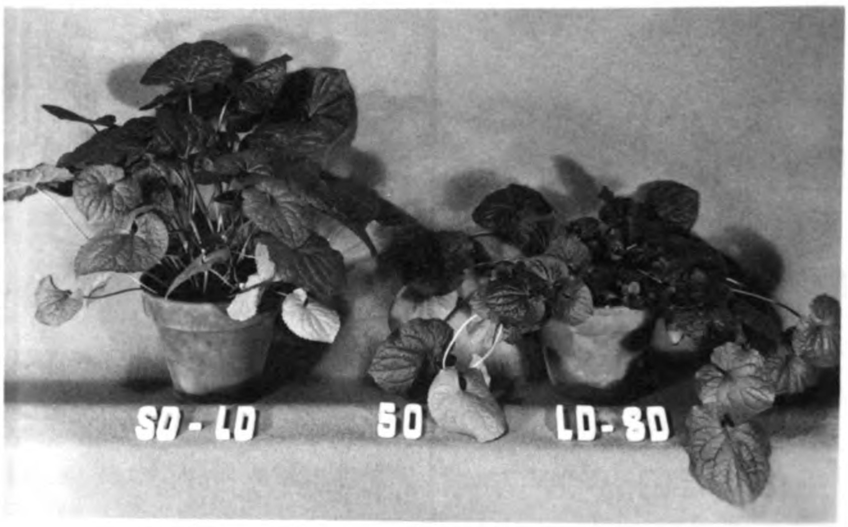

Fig. 9. Violet plants grown at 50° F. night temperature: Left, exposed to short days for 13 weeks followed by long days for 12 weeks; Right, exposed to long days for 13 weeks followed by short days for 12 weeks; All plants grown concurrently in a greenhouse.

the two temperatures and were moved from the short to the long photoperiod or from the long to the short photoperiod 13 weeks after the start of the treatments. This allowed them to grow for 12 weeks under the new photoperiod before the end of the experiment. It is interesting to note that the plants in these figures on the left, moved from the short to the long photoperiod at each temperature, have undergone a complete changeover and exhibit the typical long day foliage-type. The leaves produced under the short photoperiod prior to reversing the day length have gradually turned yellow and died as the new, larger leaves have grown and shaded them. The plants (right, Figures 8 and 9), moved from a long to a short photoperiod, had produced large leaves under the former long day treatment. These leaves hang down around the edge of the pots. Many of them have already turned yellow and have been removed. The smaller, short photoperiodic foliage-type will be noticed filling in the area around the crown of the plant.

Foliage produced under one photoperiod apparently tended to die under the other photoperiodic treatment. After changing the photoperiod, new leaves with a different petiole length tended to force the older leaves aside. The small leaves produced under short days were shaded by the large leaves produced under the long days and gradually their source of light was reduced so that they

TABLE III

INFLUENCE OF PHOTOPERIOD ON CHASMOGAMOUS FLOWER PRODUCTION

GROUP II (40° SHORT DAYS)

Number of weeks after treatment was begun	Average number of flowers produced per plant	Average stem length in inches	Average flower diameter in inches
8	0	0	0
9	.02	3.25	1.00
10	.05	3.00	1.13
11	.05	3.88	1.13
12	.16	3.93	1.07
13	.12	4.35	.87
14	.12	3.81	.94
15	.27	4.39	1.00
16	.36	4.38	1.04
17	.36	5.26	1.23
18	.88	5.14	1.07
19	1.15	5.18	1.26
20	.24	4.91	1.00
21	.30	3.91	.99
22	0	0	0
23	.06	3.75	1.12
24	.18	4.04	1.27
25	.58	2.93	.80
Total	4.90	66.11	16.92
Average	.31	4.13	1.06

TABLE IV

INFLUENCE OF PHOTOPERIOD ON CHASMOGAMOUS FLOWER PRODUCTION

GROUP IV (50° SHORT DAYS)

Number of weeks after treatment was begun	Average number of flowers produced per plant	Average stem length in inches	Average flower diameter in inches
8	.07	2.67	1.00
9	.16	2.89	1.18
10	.14	2.63	1.17
11	.19	3.00	1.13
12	.49	4.21	1.17
13	.23	3.93	1.73
14	.33	4.61	1.10
15	.33	4.80	1.11
16	.53	4.84	1.14
17	1.06	4.95	1.22
18	1.45	4.79	1.17
19	2.30	4.79	1.20
20	1.09	4.46	1.17
21	1.15	4.31	1.08
22	.94	4.73	1.18
23	1.46	4.26	1.21
24	2.67	3.84	1.16
25	3.76	3.56	1.09
Total	18.35	73.27	21.21
Average	1.02	4.07	1.18

TABLE V

INFLUENCE OF PHOTOPERIOD AND TEMPERATURE ON CHASMOGAMOUS FLOWER PRODUCTION FOR PLANTS MOVED FROM LONG PHOTOPERIOD TO SHORT PHOTOPERIOD

Number of weeks after treatment was begun	Average number of flowers produced per plant	Average stem length in inches	Average flower diameter in inches
	GROUP IIA (40° F.N.T.)		
21	0	0	0
22	0	0	0
23	0	0	0
24	0	0	0
25	.7	3.11	.87
Total 5 weeks	.7	3.11	.87
Average/week	.14	3.11	.87
	GROUP IVA (50° F.N.T.)		
21	.8	2.06	.59
22	.9	2.26	.57
23	2.0	3.61	1.10
24	4.2	3.93	1.22
25	4.0	3.99	1.14
Total 5 weeks	11.9	15.85	4.62
Average/week	2.4	3.17	.92

TABLE VII

INFLUENCE OF PHOTOPERIOD ON CHASMOGAMOUS FLOWER PRODUCTION.
AVERAGES FROM SUMMARY OF TABLES II THROUGH V*

Treatment number	Average number of flowers produced per plant	Average stem length	Average flower diameter
II	.33	4.13	1.06
IV	.61	4.07	1.18
L.S.D. .05	.46	.53	.098
L.S.D. .01	.63	.72	.13
IIA	.14	3.11	.87
IVA	2.4	3.17	.92
IA	.19	3.87	.67
IIIA	.36	3.57	.67

*Data in treatments II and IV for average number of flowers produced per plant is based only on data up to the 21st week.

were unable to exist. Many of them turned yellow and died.

Reproductive Growth

The flowers produced by the short photoperiod in both temperature treatments were of the chasmogamous type. The flowers produced by the long photoperiod in both temperature treatments were of the cleistogamous type (Figure 3). Madge (1929) obtained results similar to these in her work at Royal Halloway College.

Chasmogamous Flower Production. The data in Tables III and IV show flower production, flower diameter, and peduncle length of the chasmogamous flowers produced by the short photoperiodic treatments. No significant difference at the 5 per cent level was found between the production at the 50 and the 40° F.N.T. (Table VII).

The difference in the length of the peduncles produced under the two temperatures was not found to be significant at the 5 per cent level. The flowers produced under the 50° F.N.T. and short photoperiod were on the average 0.12 inches larger in diameter than were the flowers produced under the 40° F.N.T. This was significant at the 5 per cent level (Table VII).

The production of chasmogamous flowers in the short photoperiod, 40° F.N.T. treatment ceased in the 21st week. Two weeks later on April 24th the production of chasmogamous flowers was resumed. During the 22nd week a considerable number of cleistogamous flowers were observed on these plants and they continued to be produced through the 24th week. An attempt was made to find a physiological explanation for the change from the production of chasmogamous to cleistogamous flowers and back to chasmogamous flower production in less than four weeks.

The causal factor involved in this change in flower type was obviously one of photoperiod. It may be that the cloth used to shade the plants in the 40° F.N.T. house was not of sufficient density to completely shut out the more intense light of the early spring months. At the date of repotting in the 18th week, a larger black cloth was required to completely cover the plants. This was of double thickness and may have been the cause of changing the plants into a short day behavior, so that they again produced chasmogamous flowers five weeks later and continued to increase the production during the remainder of the investigation. It is of interest to note that 20 plants which were retained under short photoperiod after the 25th week, continued to produce chasmogamous flowers in large quantities until the plants were discarded in the middle of June.

<u>Cleistogamous Flower Production</u>. Cleistogamous flowers were produced on plants grown under long days at both the 40 and 50° F.N.T. throughout the investigation.

Reversal of Photoperiod. The production of chasmogamous flowers by those plants moved from long to short days the 13th week is shown in Table V. Production of chasmogamous flowers began 8 weeks after the plants were exposed to short days in the 50° F.N.T. (21st week). The flowers produced prior to the 10th week after the date of starting the short photoperiodic treatment were not of saleable quality. The flowers were small; the peduncles were short. The diameter of the flowers was 0.58 inches compared to an average of 1.06 inches for the 25 week period. The peduncles were 2.16 inches contrasted to 4.13 inches on the average for the 25 week period.

In the 40° F.N.T. treatment, those plants moved from the long to the short photoperiod after 13 weeks did not produce any chasmogamous flowers until 12 weeks after the date of starting the short photoperiodic treatment. It is likely that the cloth used at the 40° F.N.T. prior to the 18th week was inefficient at the higher light intensities of that date and the production of chasmogamous flowers in the 40° F.N.T. and short photoperiod was undoubtedly unduly delayed.

Cleistogamous flower production ceased after 5 weeks on all plants moved from the long to the short photoperiod in the 50° F.N.T. during the 13th week. Those plants exposed to the short photoperiodic treatment in the 40° F.N.T., however, continued cleistogamous flower production for approximately 10 weeks. This was probably caused by the inefficient exclusion of light prior to the 18th week.

The plants which were moved from a short to a long photoperiod during the 13th week continued to produce chasmogamous flowers for a period of 5 weeks (Table VI). The slight difference in the extended period of production of chasmogamous flowers on plants in the two different night temperatures shows that the temperature had little effect upon the rate of the development of the flower types after the type had been differentiated.

The production of cleistogamous flowers on those plants moved from a short to a long photoperiod in the 13th week began 9 weeks after the date of moving.

Influence of Leaf Type on Flower Type. Six weeks after efficient shading was applied to the 40^{o} F.N.T. and short photoperiodic treatment the chasmogamous flowers were again produced, leaving only one week during which the chasmogamous flowers were not produced (Table III). Yet it required 10 weeks after the plants were moved from a long to a short photoperiodic treatment at 50^{o} F.N.T. for good quality chasmogamous flowers to be produced (Table V). It seems reasonable to draw the conclusion from these two observations, that for chasmogamous flowers to be produced, the short photoperiodic foliage-type must first be present to produce a stimulus, the cause of chasmogamous flower buds. It required four more weeks for plants to produce chasmogamous flowers when they were moved from a long to a short photoperiod than when all buds were removed from the plants which were abundant in the short day foliage-type and were continued in a short photoperiod. For plants which were moved to the short photoperiod to produce chasmogamous flowers, they first had to produce the short day type of foliage in order to produce the chasmogamous flowering stimulus.

Similarly it seems likely that the long day type of leaves are necessary to produce the stimulus which causes the formation of cleistogamous flowers. This is shown by a similar period of nine weeks which passed before the production of cleistogamous flowers began on those plants moved from the short to the long photoperiod. The conception is further supported by the fact that the plants moved from the long to the short photoperiod in the 50° F.N.T. ceased cleistogamous flower production after a period of five weeks.

It is believed that the results obtained in the 40° F.N.T. short photoperiodic treatment did not follow the results obtained in the other treatments because of the ineffective cloth used for shading the plants. This meant that the plants had been exposed to a longer photoperiod than was intended. This photoperiod may not have been long enough to cause the dissipation of the short photoperiodic type of leaves. As soon as the short photoperiod was returned the leaves were already present to produce the stimulus which might cause the production of chasmogamous flowers. The continued production of cleistogamous flowers by the plants moved to this treatment from the long photoperiod for 10 weeks after the date of moving (13th week), was also apparently caused by the accidental extension of the photoperiod prior to the 18th week. This extension was sufficient to cause the long day type of foliage to produce the stimulus which may have been sufficient to cause the cleistogamous flower production.

On the basis of this theory it would appear to require five weeks for a flower of Viola odorata to develop after it has been initiated. This is similar to the findings of Garner and Allard (1920) who concluded that it took about one month to produce chasmogamous flowers. In Garner and Allard's work no mention was made of the type of foliage on the plants at the beginning of the treatment. In addition to the five week period required for the flower development an additional four week period seems to be essential for the plants to produce the type of leaf which may be the source of the flower stimulus.

Application to Greenhouse Operation. Commercial flower production will take place only under a short photoperiod. It requires 10 weeks of this photoperiod to produce saleable flowers when the plants are grown at a 50° F.N.T. The flowers are larger and there is a greater leaf area per plant when they are grown at 50 rather than at 40° F.N.T.

A greenhouse operator desiring to keep his planting of violets in good production for the late spring markets, should control the photoperiod received by the plants at 8 hours and the temperature at 50° F.N.T. It appears of little value to supply a long photoperiod to obtain vigorous growth, since under the shorter photoperiod, the long day foliage type tends to dissipate. Cleistogamous flowers would be initiated in the axils of the long day type of leaves. Unless seed production was desired, unnecessary utilization of carbohydrates would take place.

By furnishing the large well grown plants with an 8 hour photoperiod and a 50° F.N.T. for 10 weeks prior to the time they are planted in the greenhouse in the fall, the plants should produce good quality flowers almost immediately and increase the production per square foot of greenhouse bench.

SUMMARY

Plants of *Viola odorata* var. Fries Favorite were planted in sterilized soil in 4 inch pots. On November 9, 1950, the following treatments were begun: I. 43 plants exposed to a 40° F. night temperature and a 16 hour photoperiod; II. 43 plants exposed to a 40° F. night temperature and an 8 hour photoperiod; III. 43 plants exposed to a 50° F. night temperature and a 16 hour photoperiod; and IV. 43 plants exposed to a 50° F. night temperature and an 8 hour photoperiod. During the 13th week of the experiment, 10 plants were selected at random from each treatment and moved to the opposite photoperiod in the same temperature at which they had been growing.

Weekly records were made of number and size of chasmogamous flowers produced between the 8th and 25th week of treatment. At the end of the 25th week, on May 8, 1951, a comparison of vegetative growth was made by measuring the area of all of the leaves from ten plants in each treatment.

Results indicated that a photoperiod of 16 hours tended to be more favorable for vegetative growth of *Viola odorata* than a photoperiod of 8 hours. A 50° F. night temperature also tended to be more favorable for

vegetative growth than a 40° F. night temperature. Photoperiod in this investigation was more effective than temperature in reducing or increasing vegetative growth.

The short photoperiod of 8 hours favored the production of chasmogamous flowers, while the long photoperiod of 16 hours favored the production of cleistogamous flowers. A 50° F. night temperature produced larger chasmogamous flowers than did a 40° F. night temperature.

From the date of beginning the short photoperiodic treatment, it required between 8 and 10 weeks to produce chasmogamous flowers at the 50° F. night temperature, providing the short day type of foliage was not present on the plant at the beginning of the treatment. Plants moved from a short to a long day continued chasmogamous flower production for a period of approximately five weeks at either 40 or 50° F. night temperature.

The period of time required for cleistogamous flower production to begin when the plants were moved from short to long days was approximately 9 weeks. The extended period of production of cleistogamous flowers after the plants were removed from the short day length was 5 weeks.

It is suggested that the stimulus causing the production of the two different flower types in <u>Viola odorata</u> is produced by a foliage-type characteristic of the respective day lengths found to favor production of the flower types. Recommendations are made for commercial growers of violets to control the flowering period by the use of regulated day length and temperature.

The text is augmented by 9 illustrations and VII tables.

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