Studies on the Light Controlling Flower Initiation of *Pharbitis Nil.*

V. On the Light Following the Inductive Dark Period

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It has been known that the light intensity following, as well as preceding, an inductive dark period has a pronounced effect on initiation and development of inflorescences in *Xanthium pennsylvanicum*, and that the flowering response is increased by high-intensity light¹⁾. Recently it has been reported by Carr that the depressing effect of the absence of high-intensity light following a dark period in *Xanthium* may be completely overcome by supplying sucrose to the leaf²⁾. Furthermore, it is well known in *Xanthium* that a brief light period interpolated between an inductive dark period and a further period of darkness is inhibitory to flowering, the degree of inhibition depending on the length of the second dark period³⁾.

Thus, the intensity of the illumination following an inductive dark period has an important effect on photoperiodic induction of flowering in a short-day plant.

The present investigation was performed to examine the effect of intensity and quality of light in the illumination period following an inductive dark period on flower initiation of *Pharbitis* seedlings.

As has been reported previously^{4,5)}, illumination of far-red light preceding the inductive dark period inhibits flower initiation of *Pharbitis* strongly, and the flower inhibitory effect of low intensity light irradiation preceding an inductive dark period is obvious only when far-red light is included in it. Therefore, the effects on flower initiation of strong far-red light and low intensity light with or without far-red light given following an inductive dark period were investigated.

Material and Methods

The material and the procedure of experimentation were similar to those described in a previous paper⁴⁾.

Red light (600–700 m μ) was secured from a pink fluorescent lamp filtered with 2 layers of red cellophane and far-red light (700–1000 m μ) from an incandescent lamp filtered with 5 cm. water, 2 layers of red and 2 layers of blue cellophane.

Experimental Results

Experiment 1. As had been reported in previous papers^{4,5)}, illumination of far-red light of 60 kiloerg/cm.²/sec. strongly inhibits flower initiation when it precedes an inductive dark period. In this experiment the effect of far-red light illumination following an inductive dark period was investigated.

The plants were placed 16 or 12 hours in darkness and subsequently exposed to far-red light of 60 kiloerg/cm.²/sec. (FR) for various periods ranging from 30 minutes to 8 hours, and thereafter transferred to continuous illumination of natural daylight supplemented with incandescent light at night.

The flowering responses of the plants are shown in Table 1. Far-red light illumina-

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Table 1. Effect of far-red light illumination following 16- and 12-hour dark periods on the flower initiation of *Pharbitis* seedlings.
Intensity of far-red light (FR): 60 kiloerg/cm.²/sec.
(Treated on May 13 and dissected on May 27, 1958)

Treatment	No. of plants dissected	% of plants with flower buds	No. of flower buds per plant	% of plants with terminal flower bud
16 ^h d	40	100	4.1	95.0
16 ^h d→30'FR	39	100	3.7	79.5
" → 2 ^h FR	39	100	3.7	77.0
" → 4 ^h FR	38	100	3.2	55.3
" → 8 ^h FR	39	100	3.2	56.5
12 ^h d	40	2.5	0.0	0
12 ^h d→30'FR	39	0	0	0
" → 2 ^h FR	39	15.8	0.2	0
" → 4 ^h FR	38	10.5	0.1	0
" → 8 ^h FR	40	25.0	0.3	0

16^hd: 16-hour dark period.

16^hd→30'FR: 16-hour dark period followed by far-red light illumination of 30 minutes.

These abbreviations will be used hereafter.

tion following a 16- or 12-hour dark period has a little influence upon the flower initiation.

The far-red light illumination following 16 hours of darkness appeared to inhibit flower initiation slightly, but following a 12-hour darkness it promoted flower initiation to some extent. In several repetitions of the same experiments, similar results were obtained and the effect of far-red light is slight in all cases.

Experiment 2. Daylight fluorescent light of 10 lux (FL) including little far-red light inhibits flower initiation only a little when followed by an inductive darkness of sufficient duration (16 hours), but promotes it strikingly when followed by darkness of 12 hours or less^{5,6}).

In the present experiment, the effect of FL illumination following a 16- or 12-hour dark period was investigated.

Plants were exposed to the daylight fluorescent light of 10 lux for various hours following 16- and 12-hour dark periods, respectively. Control plants were exposed to high-intensity light following the 16- or 12-hour darkness. As another control, two lots of plants were exposed to the daylight fluorescent light of 10 lux for 24 and 48 hours without any dark period. Results are shown in Table 2.

All lots which were subjected to a 16-hour dark period followed by various durations of FL were induced to flower as much as the control plants with which the dark period has followed by high intensity light. On the other hand, the FL illumination following a 12-hour dark period promoted flower initiation considerably. The flower promoting effect of this FL increased with increasing duration. Control plants which were exposed to the FL for 24 and 48 hours initiated no flower bud. Thus, low intensity light illumination following an inductive dark period does not inhibit flower initiation in *Pharbitis* seedlings, but promotes it when preceded by 12-hour darkness.

Table 2. Effect of the illumination of daylight fluorescent light of 10 lux following 16- and 12-hour dark periods on flower initiation of *Pharbitis* seedlings.
(Treated on June 7-9, dissected on June 23, 1958)

Treatment	No. of plants dissected	% of plants with flower buds	No. of flower buds per plant	% of plants with terminal flower bud
16 ^h d	42	100	4.3	97.7
16 ^h d → 4 ^h FL	37	100	4.6	100
// → 6 ^h FL	39	94.9	4.3	92.3
// → 8 ^h FL	40	100	4.6	95.0
// → 12 ^h FL	37	100	4.2	94.6
// → 18 ^h FL	36	100	4.3	100
// → 24 ^h FL	37	100	4.5	100
// → 30 ^h FL	34	100	4.8	100
// → 36 ^h FL	39	100	4.5	100
// → 42 ^h FL	35	100	4.6	100
// → 48 ^h FL	29	100	4.3	86.2
12 ^h d	38	94.8	1.7	0
12 ^h d → 2 ^h FL	38	100	3.1	7.9
// → 4 ^h FL	38	100	3.7	13.2
// → 6 ^h FL	38	100	4.0	36.8
// → 8 ^h FL	37	100	3.3	27.0
// → 12 ^h FL	38	100	3.4	26.3
// → 18 ^h FL	38	100	2.8	10.5
// → 24 ^h FL	39	100	3.7	35.9
// → 30 ^h FL	32	100	3.0	43.8
// → 36 ^h FL	37	100	3.3	54.1
// → 42 ^h FL	32	100	4.1	62.5
// → 48 ^h FL	37	100	4.2	59.5
24 ^h FL	38	0	0	0
48 ^h FL	39	0	0	0

FL: Daylight fluorescent light of 10 lux.

Assuming that the last process of the inductive dark period can proceed under FL to some extent, the results can be interpreted plausibly. That is: a 16-hour dark period induces maximum flowering response and further lengthening of the dark period does not increase flowering response; therefore, even if the last process of the inductive dark period proceeds under FL following 16-hour darkness, flowering response is not promoted. On the other hand, a 12-hour dark period can not induce maximum flowering response and further lengthening of the dark period increases flowering response remarkably; therefore, if the last process of the inductive dark period proceeds under FL following 12-hour darkness, flowering response is promoted.

Experiment 3. An experiment similar to the second one was carried out but the far-red light of 120 erg/cm.²/sec. was mixed with FL (FL+FR). As shown in Table 3, when the low-intensity light following an inductive dark period contains far-red light, flower initiation of *Pharbitis* seedling is scarcely influenced when the dark period is

Table 3. Effect of FL+FR illumination following 16- and 12-hour dark periods on flower initiation of *Pharbitis* seedlings.

FL+FR: Daylight fluorescent light of 10 lux mixed with far-red light of 120 erg/cm.²/sec.

(Treated on July 3-4 and dissected on July 16, 1958)

Treatment	No. of plants dissected	% of plants with flower buds	No. of flower buds per plant	% of plants with terminal flower bud
16 ^b d	39	100	4.3	97.5
16 ^b d → 4 ^b (FL+FR)	39	100	4.4	92.3
" → 8 ^b (FL+FR)	38	100	4.2	92.1
" → 12 ^b (FL+FR)	34	100	4.3	91.2
" → 18 ^b (FL+FR)	36	100	4.3	94.5
" → 24 ^b (FL+FR)	35	100	4.3	91.4
" → 30 ^b (FL+FR)	37	100	4.4	94.7
" → 36 ^b (FL+FR)	31	100	4.6	96.8
" → 48 ^b (FL+FR)	34	100	4.6	88.3
12 ^b d	40	90.0	1.1	0
12 d → 4 ^b (FL+FR)	38	100	1.6	0
" → 8 ^b (FL+FR)	38	100	1.7	2.6
" → 12 ^b (FL+FR)	38	94.8	1.5	0
" → 18 ^b (FL+FR)	39	89.9	1.3	0
" → 24 ^b (FL+FR)	37	89.2	1.4	0
" → 30 ^b (FL+FR)	40	95.0	1.8	2.5
" → 36 ^b (FL+FR)	36	97.0	1.9	5.6
" → 48 ^b (FL+FR)	34	100	1.8	0
24 ^b (FL+FR)	40	0	0	0
48 ^b (FL+FR)	41	0	0	0

16 hours, but it appears to be promoted slightly when the dark period is 12 hours. Control plants which were subjected to such light for 24 and 48 hours did not initiate any flower bud.

FL illumination following a 12-hour dark period promotes flower initiation more obviously than FL+FR. The last process of the inductive dark period can be assumed to be largely prevented by the far-red light.

Experiment 4. Plants were placed in darkness for 16 or 12 hours, at the end of which they were irradiated for 5 minutes with red light of 3000 erg/cm.²/sec., and immediately thereafter subjected to various hours for a second dark period. The flowering responses of these plants are shown in Table 4. The second dark period following 16 hours of darkness exerts no influence on flower initiation, but that following 12 hours of darkness promotes flowering response remarkably. The flower inhibitory effect of the second dark period which is obtained in *Xanthium*³⁾ is not observed in *Pharbitis* seedlings. The last process of the inductive dark period is presumably stable to the brief red light.

Experiment 5. Plants were given a 16-hour period consisting of two parts, a certain number of hours in the dark followed by a light period of FL or FL+FR.

Table 4. Effect of a second dark period of 2-8 hours given following a 16- or 12-hour dark periods and 5 minutes of red light.

Intensity of red light: 3000 erg/cm.²/sec.

(Treated on April 22, and dissected on May 13, 1958)

Treatment	No. of plants dissected	% of plants with flower buds	No. of flower buds per plant	% of plants with terminal flower bud
16 ^h d	38	100	5.0	100
16 ^h d → 5'R → 2 ^h d	37	100	5.0	100
" → " → 4 ^h d	40	100	5.1	100
" → " → 8 ^h d	35	100	5.0	100
24 ^h d	39	100	5.2	100
12 ^h d	38	100	1.1	0
12 ^h d → 5'R → 2 ^h d	40	100	4.3	75.0
" → " → 4 ^h d	40	97.5	4.6	90.0
" → " → 8 ^h d	39	100	4.8	94.9
20 ^h d	40	100	4.9	97.5

Table 5. Flowering response of *Pharbitis* seedlings which were subjected to a 16-hour period consisting of various hours of darkness and followed by FL or FL+FR.

FL: Daylight fluorescent light of 10 lux.

FL+FR: Daylight fluorescent light of 10 lux mixed with far-red light of 120 erg/cm.²/sec.

Group	Treatment	No. of plants dissected	% of plants with flower buds	No. of flower buds per plant	% of plants with terminal flower bud
I*	16 ^h d	37	100	4.1	100
	14 ^h d → 2 ^h FL	40	100	4.1	97.5
	12 ^h d → 4 ^h FL	39	100	3.4	17.9
	10 ^h d → 6 ^h FL	39	12.8	0.2	0
	8 ^h d → 8 ^h FL	38	2.6	0.0	0
	14 ^h d	41	100	4.3	100
	12 ^h d	39	84.6	2.1	5.1
	10 ^h d	40	0	0	0
	8 ^h d	41	0	0	0
II**	16 ^h d	38	100	4.8	100
	14 ^h d → 2 ^h (FL+FR)	38	100	4.9	97.4
	12 ^h d → 4 ^h (FL+FR)	40	100	2.2	2.5
	10 ^h d → 6 ^h (FL+FR)	39	7.7	0.1	0
	8 ^h d → 8 ^h (FL+FR)	38	0	0	0
	14 ^h d	39	100	4.3	76.9
	12 ^h d	39	87.2	0.9	0
	10 ^h d	39	0	0	0
	8 ^h d	39	0	0	0

* Treated on May 22 and dissected on June 6, 1958.

** Treated on May 23 and dissected on June 7, 1958.

The first group of plants was subjected to 16-, 14-, 12-, 10- and 8-hour darkness followed by 0-, 2-, 4-, 6- and 8-hour FL, respectively. The second group was treated in the same way as the first group but far-red light of 120 erg/cm.²/sec. was mixed with FL (FL+FR). Control plants for both groups were placed in darkness for 14, 12, 10 and 8 hours and then in high-intensity light. Results are shown in Table 5.

In the first group, the plants placed in darkness for 16 hours and those given 14 hours of darkness followed by high-intensity light or 2-hour FL, were induced to flower to the same extent. But with the further decrease of the dark period, accompanied by an increasing duration of the FL, flowering response is reduced gradually, and only one out of 38 plants which were placed in darkness for 8 hours followed by 8-hour FL illumination initiated a flower primordium.

Comparing the flowering responses of the plants subjected to 12~8 hours of darkness followed by 4- to 8-hour FL illumination, and those in darkness for the same length of time but followed by high-intensity light illumination, the former initiated slightly more flower buds than the latter.

From these results it appears that the flower-inducing process taking place in the last 6~8 hours of the 16-hour dark period proceeds slightly under FL.

In the second group, similar results were obtained, but the last process of the inductive dark period appears to be inhibited more strongly by FL+FR than by FL, but less than by high-intensity light.

Discussion

Low-intensity light illumination following an inductive dark period of 16 hours does not inhibit the flowering response of *Pharbitis* seedlings whether far-red light is included or not. Furthermore, a second dark period which is given following 16 hours of darkness and 5 minute illumination with red light (3000 erg/cm.²/sec.) does not inhibit flowering response.

These phenomena observed with *Pharbitis* seedlings offer opposition to the results obtained with *Xanthium*^{1,2,3}), in which the flowering response was reduced strikingly by low-intensity light or a second dark period following an inductive dark period.

From the results of experiments 2 and 5, it appears that the last phase of the 16-hour dark period proceeds to some extent under daylight fluorescent light of 10 lux (FL) but that the first phase of the inductive dark period proceeds more readily under FL^{5,6,7}).

As had been reported previously, the first process appears to proceed easily under far-red light^{5,6,7}), but the present experiment shows that the last process is inhibited considerably by far-red light.

From the present and the previous experiments^{4,5,6,7,8}), it is concluded that the inductive dark process is relatively stable to light during the first but less stable during the last phase.

Summary

1) Far-red light or low-intensity light illumination following an inductive dark period of 16 hours has no significant influence upon flower initiation of *Pharbitis* seedlings.

2) Illumination with low-intensity light containing little far-red radiation promotes flowering response to some extent if it follows a dark period of 8~12 hours, but far-red light illumination does not.

3) The flower-promoting effect of low-intensity light illumination following a dark period of 12 hours or less decreases considerably if the far-red light of low intensity is mixed with it.

4) A second dark period separated from an inductive dark period by a brief exposure to red light does not inhibit flowering response when the first dark period is 16 hours, and promotes flowering strikingly when the first period is 12 hours.

5) The last phase of the inductive dark period appears to be relatively light stable, but less stable than the first phase.

References

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摘 要

アサガオの花芽形成を支配する光条件について

V. 暗期後の光について

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1) 16時間の暗期後に与えた近赤外光または弱光 (10 lux) は、アサガオの花芽形成にあまり影響を与えない。

2) 8~12 時間後に与えた近赤外光を含まない弱光 (10 lux) は花芽形成をかなり促進する。しかし近赤外光はこの促進効果を持たない。

3) 上記弱光の花芽形成促進効果は、弱い近赤外光 (120 erg/cm.²/sec.) を同時に与えることによって助けられる。

4) オナモミでは暗期後 5 分間赤色光を与え、それに続いてさらに第 2 の暗期 (8 時間) を与えると花芽形成が抑制されるといわれているが³⁾、アサガオではこのような現象は見られず、第 1 の暗期が 11 時間の場合には逆に花芽形成が促進される。

5) 花芽形成に有効な暗期の最後の段階は比較的光に安定で、弱光下でもある程度進み得、また短時間の赤色光照射に対しても安定だと考えられる。しかし暗期の初期段階程光に安定ではない。

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