Experimental researches on photoperiodism (1)*
Photoperiodic responses of *Salvinia*

By Shidai NAKAYAMA**

中山大：植物光周期の実験的研究 (1) サンショウモの光周期応答

I. Introduction

According to KAUFHOLD (1941), Polypodiaceae belongs to the neutral plant group (1). The writer wrote an article “Photoperiodic responses of *Salvinia*” in 1949 and stated that *Salvinia natans* (Hydropterides) is a very sensitive short-day plant and he also pointed out that this fact was very significant and interesting from viewpoint of photoperiodism (2). Since that time, the writer has observed in detail photoperiodism of this plant. The present article embodies the results obtained in summer of 1951.

II. Material and Methods

Experimental material was collected from a pond of the Department of Botany, Faculty of Science of Kyôto University. Till germination of spore, the plants had been cultured in a glass vessel of 20 cm diameter and 12 cm height filled with water; and after germination they were furnished with 2.5 L of 0.1% Knop’s nutrient solution, continuously illuminated at night with 100 Watt Mazda Lamp set at a distance of 1 m above air leaf surface. Nutrient solution was renewed once a week. Initial pH of the nutrient solution was regulated at about 6.5.

Appearance of sporocarp was ascertained with help of dissecting microscope of 10 or 20 X magnification and taked as a clew of photoperiodic response.

III. Results

(a) The number of times of photoperiodic treatment necessary to cause induction

Photoperiodic treatment was carried out from July 1 to 8 using a dark period of 17 hrs. and a light period of 7 hrs.; after the treatment the plants were returned

* Contribution from the Department of Biology Faculty of Liberal Arts and Education, Miyazaki University, No. 30.

** Department of Biology Faculty of Liberal Arts and Education, Miyazaki University, Miyazaki, Japan.
to a continuous light one. Table 1. and fig. 1 show the results of 12 days after the photoperiodic treatment. Fig. 1-A illustrates a percentage of sporocarp bearing plants; under the continuous light, sporocarps were not initiated at all, in section of one-cycle treatment 8% of the plants reacted; and then in section of two cycle treatment the majority of the plants (80%) reacted; all plants reacted in section of seven cycles of the treatment. In table 1, and fig. 1-B are shown average number of sporocarps per plant, general trend being sigmoid as plotted in fig. 1-A.

(b) On the effects of nitrogen upon the photoperiodic induction

Plants grown under the continuous illumination and supplied with Knop's complete nutrient solution, were separated into two groups on July 2; one of the two was supplied with the complete nutrient solution while the other was given a nutrient solution which lacked nitrogen as given below.

<table>
<thead>
<tr>
<th>Knop's complete nutrient solution (+N)</th>
<th>Knop's nutrient solution lacking nitrogen (−N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca(NO₃)₂ ........................................... 0.571 g</td>
<td>CaCl₂ ........................................... 0.571 g</td>
</tr>
<tr>
<td>KNO₃ .............................................. 0.143 g</td>
<td>KCl ............................................... 0.143 g</td>
</tr>
<tr>
<td>MgSO₄ ............................................. 0.143 g</td>
<td>MgSO₄ ............................................. 0.143 g</td>
</tr>
<tr>
<td>KH₂PO₄ ........................................... 0.143 g</td>
<td>KH₂PO₄ ........................................... 0.143 g</td>
</tr>
<tr>
<td>FeCl₃ ............................................. trace</td>
<td>FeCl₃ ............................................. trace</td>
</tr>
<tr>
<td>H₂O ................................................ 1000 cc</td>
<td>H₂O ................................................ 1000 cc</td>
</tr>
</tbody>
</table>

On July 12 (10 days later), short-day treatment was started, applying dark period of 16 hrs. and light period of 8 hrs. immediately after a symptom lacking nitrogen appeared. After photoperiodic treatments were repeated 5 times, the plants were taken back to the continuous light condition. Table 2 tabulates the results observed on July 17 (5 days after treatment). There were remarkable differences between the +N and −N plants; nitrogen is decisively effective upon the formation and development of sporocarp.
(c) On the critical dark period

Dark treatment was begun on July 6 and each section was subjected to different lengths of dark period; cycles of varying dark period 0, 7, 8, 9, 10, 11 and 12 hrs. were employed combining with a constant light period of 16 hrs. Each section was exposed to photoperiodic treatments for 9 times, and then it was taken back to the continuous illumination. Table 3 indicates the results obtained on July 31 (25 days after treatment). There was no microscopic evidence of sporocarp; i.e., critical duration of dark period not be determined.

(d) On the translocation of the stimulus causing the primordia of sporocarp.

Plants bearing 7 pairs of air leaves were used, and the air leaves of terminal

Table 3. Experiment on the critical dark period. Observed on July 31 (25 days after treatment).

<table>
<thead>
<tr>
<th>Length of dark period in hours</th>
<th>0</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of light period in hours</td>
<td>24</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>% of plants with sporocarp</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No. of plants used</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>
portion were defoliated as in the section of table 4 on July 13. Each section was
given short-day treatment (from 8 A.M. to 4 P.M.) from July 14 to July 25, afterward
it was taken back to the continuous light. During the experiment, newly developed
air leaves in the terminal part were defoliated before expanding. Table 4 shows the
results recorded on July 31 (18 days after the treatment). Sporocarp was not
initiated at all in the section deprived of air leaves, whereas number of sporocarp

Table 4. On the translocation of the stimulus for the initiation of sporocarp.
  Observed on July 31 (17 days after treatment).

<table>
<thead>
<tr>
<th>No. of the air leaf</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>14</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of plants with</td>
<td>short day</td>
<td>0.0</td>
<td>40.0</td>
<td>70.4</td>
<td>74.3</td>
<td>92.4</td>
</tr>
<tr>
<td>sporocarp</td>
<td>long day</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No. of sporocarp</td>
<td>short day</td>
<td>0.0</td>
<td>±0.00</td>
<td>0.8</td>
<td>±0.32</td>
<td>1.7</td>
</tr>
<tr>
<td>per plant</td>
<td>long day</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No. of plants used</td>
<td>short day</td>
<td>17</td>
<td>15</td>
<td>27</td>
<td>35</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>long day</td>
<td>14</td>
<td>11</td>
<td>17</td>
<td>11</td>
<td>7</td>
</tr>
</tbody>
</table>

and a percentage of reacted plants were proportional to that of air leaves. Sporocars
were formed on the growing point of the water leaves in the terminal part deprived of air
leaves (see fig. 2).

IV. Discussion

Salvinia natans can react sensitively to the short-day treatment, though very few plants
reacted in the one cycle of photoperiodic treatment, most plants (80%) in the two cycles, and
all plants in the seven cycles. Therefore the writer concludes that Salvinia natans is a very
sensitive short-day plant as Xanthium (3) and Ipomoea (4).

The effect of nitrogen upon the formation and development of sporocarp accords well with
the previous studies (5, 6, 7, 8), namely, nitrogen is effective for the formation and development
of the reproductive organ (sporocarp).

In this experiment, the critical length of dark period was not determined, hence,
0, 7, 8, 9, 10, 11 and 12 hrs. dark periods combined respectively with a constant
light period of 16 hrs., each section was given 9 times of photoperiodic treatment but in vain. From the above fact, the writer presumes that in the light period of 16 hrs. the critical dark period does not fall between 7 and 12 hrs. Nevertheless, the critical dark period lies between about 10.30 and 10.49 hrs. in natural day length; i.e., according to the writer's experiment (2) in Sendai (36°16'N) sporocarp was observed with the naked eye on September 4, namely the dark period and the light period from August 19 to August 29 when sporocarp is formed respectively are about 10.40 hrs. and 13.20 hrs.

The above fact shows that the dark period of about 10.40 hrs. is effective for the formation and development of sporocarp. And as the fact that the length of light period affects the length of the critical dark period (9), it is considered that the light period of 16 hrs. in this experiment interfered with the effective length of the dark period, and that the critical dark period combined with the light one of 16 hrs. should be over 12 hrs. Another test to verify it again will be run in the near future.

The completely defoliated plant does not initiate sporocarp even under short-day treatment, so that it is considered that photoperiodic perception is performed by the air leaf. And from the fact that sporocarp is formed on the growing point at the base of the water leaves without air leaf, it is plausible that the stimulus causing the primordia of sporocarp move to the growing point at the base of the water leaves which are at some distance from the air leaves. Further investigation with a different method and without any defect is now under way.

V. Summary

(1) Short-day plant, *Salvinia natans* was used as the material and the photoperiodism was studied.

(2) In one cycle of short-day treatment 8% of plants formed sporocarp, but 80% in two cycles and 100% in seven cycles, and hence *Salvinia* plant is considered very sensitive short-day plant.

(3) Nitrogen is effective upon the formation and development of the sporocarp.

(4) In this experiment, the critical dark period could not be decided; it is considered that the critical dark period exists over 12 hrs. in the combination with the light period of 16 hrs.

(5) Photoperiodic perception is performed only on the air leaf; the stimulus for the initiation of sporocarp move to the growing point of the water leaves of the plant deprived of air-leaf. This fact is also the case with Spermatophyta.

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References

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(4) Nakayama Shidai: Ecol. Rev., 11, 188 (1948)
(7) Denffer, D.: Planta, 89, 418 (1940)
(8) Nakayama Shidai & Araki Tokuzō: (in the press)

要 約

(1) 短日植物のサンショウモを使って光週性を研究した。
(2) 短日処理1回では全植物の8％，2回では80％，7回では全部の植物が反応する。故にサンショウモは鈍敏な短日植物といえる。
(3) Nは子囊果の形成・発育に有効である。
(4) 限界暗期は決定できなかった。しかし，明期16時間の場合，限界暗期は12時間以上の所にあるらしい。
(5) 光週処理の感受は気温だけが行い，水温は直接関係しない。子囊果形成刺激は気温から水温基部の生長点に転移する。刺激伝達の点は，種子植物の場合と変らない。