Inhibition of Bulb Development in *Allium wakegi* Araki under a High Red/far-red Photon Ratio

Hiroko Yamazaki, Ryu Oi, Takaaki Nishijima and Hiroyuki Miura

1Department of Applied Physiology, National Research Institute of Vegetables, Ornamental Plants and Tea, Ano, Mie 514-2392
2Central Research Institute, Mitsui Chemicals Inc. Kasamacho, Sakae, Yokohama 247-8567

**Summary**

Effects of the red (R) to far-red (FR) photon ratio on bulb development in *Allium wakegi* were investigated. Field experiments were carried out in spring and summer, in which plants were covered with three kinds of acrylic resins: a normal clear one with a piece of white cheesecloth (control), one with low transmittance in a R region, and another with low transmittance in a FR region. The R/FR (660±5 nm/730±5 nm) photon flux density ratios in the control, R-intercepted, and FR-intercepted devices under natural light were 1.00, 0.53, and 1.73, respectively.

In both experiments the FR-intercepted treatment inhibited an increase in bulb fresh weight, bulb dry matter percentage, and bulbing index (maximum diameter/neck diameter of a bulb). In the summer experiment, the plants in the FR-intercepted device did not initiate scaly leaves which were formed by all plants in the other treatments. These results show that bulb development of *A. wakegi* was inhibited under the high R/FR photon ratio. This effect was more obvious in the summer than in the spring experiments. Plants under low R/FR photon ratio produced bulbs similar to the control.

**Key Words:** bulb development, Far-red light, R/FR photon ratio, *Allium wakegi*.

**Introduction**

Light quality affects several aspects of plant growth and development. For example, stem elongation rate is affected by the R/FR photon ratio (Holmes and Smith, 1975; Morgan and Smith, 1976). Many botanical experiments on light quality have been performed under artificial light. Recently, covering materials with selective absorption of a R or FR region were developed (Murakami et al., 1995). These kinds of materials enable researchers to regulate the R/FR ratio under natural light (Cui et al., 1995).

Some *Allium* species, including onion and *A. wakegi* Araki develop bulbs in response to a long-day stimulus. Terabun (1965) found that onion bulb development was promoted by FR irradiation and inhibited by R irradiation. That FR irradiation is essential for onion bulb development was reported by Mondal et al. (1986b) and Lercari and Deitzer (1987). Presuming that FR also controls bulb development in *A. wakegi*, we determined the effects of the R/FR photon ratio on the processes. The ratio in the field was regulated by covering the plants with acrylic resins which had low transmittance in a R or FR region.

**Materials and Methods**

Two field experiments were carried out on bulbs of *A. wakegi* cv. Kiharabansei No. 1 at the National Research Institute of Vegetables, Ornamental Plants and Tea on September 17, 1994, for the spring and on August 1, 1995, for the summer experiments. Bulbs were arranged, 2 lines in a row. Distances between lines and plants in the line were 30 cm and 20 cm, respectively. Fertilizer was applied at the rate of 3N-3P2O5-3K2O kg \* a⁻¹. In the summer experiment the field was shaded with a sheet of black cheesecloth 1.5 m above the ground, and the row was mulched with rice straws. The shade with black cheesecloth had very little influence on the R/FR photon ratio.

Three kinds of covering devices (180 cm length \* 90 cm width \* 60 cm height) were placed over the row on March 27, 1995 for the spring experiment and on August 1, 1995 for the summer experiment. The covering devices were made of a clear acrylic resin, acrylic resin with low transmittance in a R region, and acrylic resin with low transmittance in a FR region. The device made of a clear resin was covered with a piece of white cheesecloth (control) to adjust light intensity equivalent to the other devices.

Plant growth and bulb development were measured at 2-week interval from March 27 to May 8 in the spring experiment and on September 13 in the summer.
experiment. The extent of bulb development was estimated from bulb fresh weight, bulb dry matter percentage, bulbing index, and the formation of scaly leaves inside the bulbs. Bulb dry weight was measured after drying at 80°C for 3 days. Bulbing index was calculated by dividing the maximum diameter by the neck diameter of a bulb. When plants of \textit{A. wakegi} are grown under a long-day condition, new leaf blades cease to elongate and begin to form thick leaf sheaths. We called such leaves scaly leaves.

Spectral photon flux distribution in the three devices was measured under natural light with a portable spectroradiometer (LI-1800C, LI-COR).

**Results**

1. Spectral photon flux distribution

Spectral photon flux distribution in the three devices is shown in Fig. 1. The R-intercepted and FR-intercepted devices had lower photon flux densities in the range of 600 to 700 nm and 660 to 800 nm than the control device had, respectively. The photosynthetic photon flux densities and R/FR (660±5nm/730±5nm) photon flux density ratios in the three devices are shown in Table 1. The R/FR photon flux density ratios in the control, R-intercepted and FR-intercepted devices were 1.00, 0.53, and 1.73, respectively.

2. Spring experiment

When first covered in the spring experiment, the plants of \textit{A. wakegi} had 22 tillers per plant, were 54 cm in height, and the shoot weighed 581 g. Bulb size and development, as expressed as fresh weight and as bulbing index, respectively (Fig. 2), increased under three devices during 42-day growing period. The bulb development was accompanied with an increase in bulb dry matter percentage.

Bulb fresh weight, bulb dry matter percentage, and bulbing index in the FR-intercepted device tended to be less than those in the other devices (Fig. 2), but scaly leaves formed on all plants by April 24. Little differences in bulb development arose between the control and R-intercepted devices.

3. Summer experiment

Bulb fresh weight, bulb dry matter percentage, and bulbing index in the FR-intercepted device were significantly lower than those in the other devices (Table 2).

![Graph](image1.png)

**Fig. 1.** Spectral photon flux density distribution in the three covering devices under natural light. The control device was made of a normal clear acrylic resin and covered with a piece of white cheesecloth. The measurement was conducted around noon on a fine day (March 20, 1995) with nothing inside.

![Graph](image2.png)

**Fig. 2.** Effects of the R/FR photon ratio on bulb fresh weight (A), bulb dry matter percentage (B) and bulbing index (C) in \textit{A. wakegi} in the spring experiment. The plants were grown in the control device (○), R-intercepted device (□) and FR-intercepted device (△). Data are given as the mean±the SE.

<table>
<thead>
<tr>
<th>Covering devices</th>
<th>PPFD (μmol m⁻² s⁻¹)</th>
<th>R/FR (660±5nm/730±5nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>958.7</td>
<td>1.00</td>
</tr>
<tr>
<td>R-intercepted</td>
<td>1057.0</td>
<td>0.53</td>
</tr>
<tr>
<td>FR-intercepted</td>
<td>1141.0</td>
<td>1.73</td>
</tr>
</tbody>
</table>

PPFD and R/FR ratio were calculated from data in Fig. 1.
Scaly leaves formed on all plants under the control and R-intercepted devices, whereas they failed to form on plants under the FR-intercepted device (Fig. 3). Plants under the FR-intercepted device differentiated significantly more leaves than plants under the control and R-intercepted devices did. These results indicate that the primordia in bulbs under the FR-intercepted device differentiated into leaves rather than into scales.

R-intercepted treatment did not increase the bulbing index nor bulb fresh weight although it resulted in significantly higher dry matter percentage of bulbs than the control. There was no significant difference in plant height among the three treatments (Table 2).

**Discussion**

Studies have shown that FR is involved in onion bulb development, e.g. when onion plants were exposed to 8 hr sunlight followed by supplementary irradiation with R, FR, and blue light, only the plants exposed to FR developed bulbs (Terabun, 1965). Likewise, onion bulbs failed to develop when grown under daylight fluorescent lamps which emitted very little far-red energy (Terabun, 1971; Lercari and Deitzer, 1987). Bulb development was advanced in onion plants grown at high plant density (Mondal et al., 1986a), because crowding decreased the R/FR photon ratio as a result of radiation interception by the leaf canopy (Mondal et al., 1986c). Our assumption that FR is also essential for bulb development of *A. wakegi* proved correct as bulb development of *A. wakegi* was inhibited in the FR-intercepted device which provided a high R/FR photon ratio.

When onion plants were grown under R/FR photon ratios of 0.86, 1.41, and 2.88, bulb development was promoted as the R/FR photon ratio decreased (Mondal et al., 1986b). This implies the involvement of phytochrome in onion bulb development. Phytochrome is probably involved in bulb development of *A. wakegi* because when our plants were grown under the R/FR photon ratios of 0.53, 1.00, and 1.73, bulb development was completely inhibited under the R/FR photon ratio of 1.73. However, there were no clear differences in bulb development between the R/FR photon ratios of 1.00 and 0.53. Temperature and photoperiod in our experiments were favorable for bulb development. So, the plants under the R/FR photon ratio of 1.00 developed bulbs so rapidly that we did not detect the promotive effect of the R/FR photon ratio of 0.53. Further experiments are needed to test the effects of low R/FR photon ratios.

**Table 2.** Effects of R/FR photon ratios on bulb development and plant growth in *A. wakegi* in the summer experiment.

<table>
<thead>
<tr>
<th>Covering</th>
<th>Bulb fresh wt (g)</th>
<th>Bulbing index</th>
<th>Bulb dry matter percentage</th>
<th>% of plants with scaly leaves</th>
<th>No. of leaves per tiller</th>
<th>Plant height (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>1.18 a</td>
<td>2.41 a</td>
<td>19.8 b</td>
<td>100</td>
<td>3.0 b</td>
<td>35.0 a</td>
</tr>
<tr>
<td>R-intercepted</td>
<td>1.02 b</td>
<td>2.43 a</td>
<td>20.7 a</td>
<td>100</td>
<td>2.9 b</td>
<td>34.7 a</td>
</tr>
<tr>
<td>FR-intercepted</td>
<td>0.75 c</td>
<td>1.82 b</td>
<td>14.5 c</td>
<td>0</td>
<td>3.9 a</td>
<td>34.5 a</td>
</tr>
</tbody>
</table>

* Mean separation by Tukey’s test, P = 0.05

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**Fig. 3.** Shapes of a leaf inside a bulb grown in the FR-intercepted, R-intercepted and control devices from the left to the right. Plants in the R-intercepted and control devices formed scaly leaves.
The inhibitory effect of the high R/FR photon ratio was more obvious in the summer than in the spring. In the summer experiment, the plants were covered with the devices throughout their growth, whereas in the spring, the plants were covered during mid-course of their growth cycle (March 27). As apparent bulb development in *A. wakegi* cv. Khitarabane NO. I normally begins in early April (Yamazaki et al., 1995), the plants on March 27 did not develop bulb. But time lag probably exists between induction by a long-day stimulus and apparent bulb development. Therefore, the plants might be already induced by a long-day stimulus on March 27. This may be one of the reasons for the small effect of the high R/FR photon ratio in the spring experiment. There is another distinct difference between the two experiments; plants in the spring experiment were exposed to low temperature prior to long-day condition which probably has promotive effect on bulb development.

*A. wakegi* is normally used as a leaf vegetable in Japan, so that bulb formation restricts the period of cultivation because it spoils the quality. Although hard acrylic materials were used in these experiments, soft and thin materials with the same properties as the acrylic ones have been developed, which are fit for practical use. Thus, we need to learn how to regulate the R/FR photon ratio with such covering materials to inhibit bulb development in *A. wakegi* in the spring.

**Literature Cited**


赤色光／遠赤色光比の高い条件におけるワケギの鱗茎発達の抑制

山崎博子1・大井 龍2・西島隆明1*・三浦周行1

1野菜・茶業試験場生理生態部 514-2392 三重県安芸郡安浦町
2三井化学（株）総合研究所 247-8567 横浜市栄区空間町

**要約**

赤色光（R）または遠赤色光（FR）の透過率の低い2種類の被覆資材を利用してR/FR 比を調節し、その変化がワケギの鱗茎形成に及ぼす影響について検討した。試験は春と夏の2回、圃場で生育中のワケギに資材を被覆処理する形で行った。被覆装置のR/FR（660±5 nm/730±5 nm）光量子束密度比は対照区（透明資材×白日光）R 減少区およびFR 減少区でそれぞれ1.00, 0.53, 1.73 であった。

両試験ともFR 減少区でワケギの鱗茎新鮮重、鱗茎乾物率および肥大指数（鱗茎径／首部径）が低くなり、鱗茎の発達はFR 減少区、すなわち高 R/FR 条件において抑制された。この結果は冬試験より夏試験においてより顕著であった。対照区と R 減少区の鱗茎の発達程度には大きな差がみられず、低 R/FR 条件の鱗茎発達における影響は明らかでなかった。

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