Interactive Effects of Photoperiods and Plant Growth Regulators on the Development of Flowering Spikes and Tubers in Chinese Yams (*Dioscorea opposita*) cv. Ichoimo

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**Summary**

The interaction between photoperiods and plant growth regulators [gibberellin A3 100ppm (GA), uniconazol P 25ppm (Uni), n-propyl dihydro-jasmone 50ppm (PDJ), and salicylic acid 1000ppm (SA)] on the development of the main shoots, spikes, and aerial and new tubers in Chinese yam (*Dioscorea opposita* Thunb. cv. Ichoimo) plants was observed. The untreated control plants yielded the longest main shoots followed by GA, SA, PDJ, and Uni. Plant, treated with growth regulators, grew more under a 24-hr photoperiod than did those under an 8-hr photoperiod. GA treated plants, grown under the 24-hr photoperiod, developed spikes at a significantly lower node than that similarly treated plants grown under an 8-hr photoperiod; whereas the first flowering node on the control, GA, SA, Uni, and PDJ treated plants, grown under the 24-hr photoperiod, was equally higher than comparable plants, grown under the 8-hr photoperiod. More spikes per plants were initiated under the 24-hr photoperiod than on plants grown under an 8-hr photoperiod. GA treatment severely decreased the number of spikes under the 8-hr photoperiod. Aerial and new tubers developed earlier on plants under the short day than did those under constant light, but the new tubers on the latter treatment weighted more than did those on the former. The formation of aerial tubers was severely inhibited by GA but promoted by Uni under both photoperiods, while the growth of new tubers was significantly promoted by GA and significantly inhibited by Uni. PDJ and SA had no effect on the growth of aerial and new tubers.

**Key Words:** *Dioscorea opposita*, photoperiod, plant growth regulator, spike, tuber.

**Introduction**

Previously, the effects of day/night air and root zone temperatures and the initial tuber weight on the development of the main shoots, spikes, and aerial and new tubers of Chinese yam plants cv. Ichoimo were studied, but the effects of different plant growth regulators on their development were not (Yoshida et al., 1996; Yoshida and Kanahama, 1999; Yoshida et al., 1999; Yoshida et al., 2000).

Research on tuber and tuberous root crops, such as cv. Nagaimo (*Dioscorea opposita* Thunb.) (Koda and Kikuta, 1991), greater yam (*Dioscorea alata* L.) (Onjo et al., 1997), and potato (*Solanum tuberosum* L.) (Okazawa, 1967), were focused on the effect of gibberellic and jasmonic acids on the development of the main shoots, and new tubers. In this report, we examined the effect of gibberellic and n-propyl dihydrojasmonate-induced jasmonic acids, and their antagonists, uniconazole P and salicylic acid on tuber formation of Chinese yam cv. Ichoimo (*Dioscorea opposita* Thunb.). Yoshida et al. (1999) showed that the combination of photoperiod, temperature and initial tuber weight was greater than any single factor alone. Therefore, the interactive effect of photoperiods and plant growth regulators on the development of the main shoots, spikes, and aerial and new tubers were investigated.

**Materials and Methods**

*Plant materials and cultivation practice*

New tubers of Chinese yam cv. Ichoimo (*Dioscorea opposita* Thunb.) harvested from November to December, 1997 were stored at 5 °C until April, 1998, when they were cut into pieces (50 g fresh weight). These pieces of seed tubers were allowed to sprout for about one month in an unheated glasshouse and then transplanted into plastic pots (diameter 36.5 cm × height 36 cm) on 25 May, 1998. The most vigorously growing shoots to be retained as the main shoot were entwined around a pole (240 cm length). The terminal 30 to 100 cm of the shoots were supported vertically and while the remaining of the main shoots was coiled around bellow

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the pole weekly according to shoot growth. Each pot was initially administered 11.4 g magnesium lime and 22.8 g of compound fertilizer (containing 15% nitrogen, 15% phosphorus, and 15% potassium) and given a side dressing of 2 g of the former compound fertilizer per pot was supplied in July and August. Water was supplied as needed.

**Treatment**

Photoperiod treatments were started on 1 June, 1998, when a main shoot length reached 100 cm and continued until the end of December when shoot growth began to decline. Plants for the 8-hr photoperiod were grown under natural sunlight between 8:40 am and 4:40 pm, and were covered with silver polyethylene film (100% shading material) between 4:40 pm and 8:40 am. Plants for the 24-hr photoperiod were irradiated by incandescent lamp (about 2.0 μmol · m⁻² · sec⁻¹) between 4:40 pm and 8:40 am. The PGRs: gibberellin A₃ (100ppm : GA), salicylic acid (1000ppm : SA), uniconazole P (25ppm : Uni), and n-propyl dihydrojasmonate (50ppm : PDJ) containing 0.01% Tween 20, were sprayed on the leaves at a weekly interval during the photoperiod treatment until the cessation of main shoots growth in the 8-hr photoperiod group on August 19 or in the 24-hr photoperiod group on September 21. Control plants were sprayed with distilled water plus 0.01% Tween 20. Twelve plants were used in each treatment.

The fresh weights of aerial and new tubers were recorded three times: 1) for the 8-hr photoperiod group at the cessation of shoot growth on August 19; 2) for the 24-hr group on September 24, and 3) both groups at the time of shoot dieback at the end of December. Three to five plants were harvested each time.

**Results**

**Shoot growth**

The main shoots of PGR-treated plants, grown under the 24-hr photoperiod, were longer than those grown under the 8-hr photoperiod (Fig. 1). The main shoots of the plants, grown under the 8-hr photoperiod, stopped elongating in early August, compared to plants, grown under the 24-hr photoperiod, which ceased growing in early September. Shoot dieback under the 8- and 24-hr photoperiods occurred in early November and early December, respectively (Table 1). The mean final lengths of the main shoots on PGR-treated plants, grown under the 8-hr photoperiod, were shorter than comparable plants grown under the 24-hr photoperiod. Under the 8-hr photoperiod, the control and GA-treated plants produced the longest main shoots while those treated with SA and PDJ and Uni were successively shorter. Under the 24-hr photoperiod, the un-

![Graph](image)

**Fig. 1.** Growth curves of the shoots of Chinese yams treated with various plant growth regulators (PGR) and grown under the 8- and 24-hr photoperiods. Vertical bars represent S.E. Arrows indicate sampling dates of aerial and tubers.

<table>
<thead>
<tr>
<th>Plant growth regulator</th>
<th>Photoperiod (hr)</th>
<th>No. of plants observed</th>
<th>No. of plants with a spike</th>
<th>Node position of the first spike</th>
<th>Node position of the final spike</th>
<th>Total no. of spikes/Plant</th>
<th>Date of spike emergence</th>
<th>Date of shoot dieback</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cont</td>
<td>8</td>
<td>12</td>
<td>11</td>
<td>48.4 ab</td>
<td>89.9 abc</td>
<td>42.5 ab</td>
<td>Jun. 21</td>
<td>Nov. 9</td>
</tr>
<tr>
<td>GA</td>
<td>8</td>
<td>12</td>
<td>10</td>
<td>49.7 abc</td>
<td>82.0 ab</td>
<td>33.3 a</td>
<td>Jun. 29</td>
<td>Nov. 9</td>
</tr>
<tr>
<td>SA</td>
<td>8</td>
<td>12</td>
<td>11</td>
<td>52.0 abc</td>
<td>80.9 ab</td>
<td>29.9 a</td>
<td>Jun. 29</td>
<td>Nov. 9</td>
</tr>
<tr>
<td>Uni</td>
<td>8</td>
<td>12</td>
<td>12</td>
<td>47.1 a</td>
<td>87.6 abc</td>
<td>41.5 ab</td>
<td>Jun. 21</td>
<td>Nov. 12</td>
</tr>
<tr>
<td>PDJ</td>
<td>8</td>
<td>12</td>
<td>12</td>
<td>50.3 abc</td>
<td>74.2 a</td>
<td>25.7 a</td>
<td>Jun. 29</td>
<td>Nov. 9</td>
</tr>
<tr>
<td>Cont</td>
<td>24</td>
<td>12</td>
<td>12</td>
<td>55.3 abcd</td>
<td>137.7 e</td>
<td>83.3 c</td>
<td>Jun. 29</td>
<td>Dec. 7</td>
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<td>12</td>
<td>5</td>
<td>66.0 d</td>
<td>106.8 cd</td>
<td>48.0 ab</td>
<td>Jul. 5</td>
<td>Dec. 7</td>
</tr>
<tr>
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<td>24</td>
<td>12</td>
<td>11</td>
<td>65.6 de</td>
<td>107.2 cd</td>
<td>46.5 ab</td>
<td>Jul. 5</td>
<td>Dec. 7</td>
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<tr>
<td>Uni</td>
<td>24</td>
<td>12</td>
<td>12</td>
<td>59.3 cde</td>
<td>112.9 d</td>
<td>61.3 b</td>
<td>Jun. 29</td>
<td>Dec. 11</td>
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<tr>
<td>PDJ</td>
<td>24</td>
<td>12</td>
<td>9</td>
<td>58.9 bede</td>
<td>100.5 bcd</td>
<td>50.0 ab</td>
<td>Jul. 5</td>
<td>Dec. 7</td>
</tr>
</tbody>
</table>

* Values in the same column followed by the same letter are not significantly different at P ≤ 0.05.

* Date indicates the emergence of flower bud observed on 50% or more plants.
treated control had the longest main shoots followed successively by plants treated with GA, SA, PDJ, and Uni. Plants treated with same PGR had longer main shoots under constant light than under the short day treatment.

PGR had little influenced on the number of leaves in the main shoots grown under the 8- hr photoperiod; the largest number of leaves was produced by the control plants (Fig. 2). Those plants treated with PDJ, Uni, SA, and GA had successively fewer leaves. Similarly, under the 24- hr photoperiod, the control plants had the most leaves followed by those treated with Uni. Plants sprayed with GA, SA, and PDJ had equally small number of leaves. Irrespective of treatments, plants grown under the 24- hr photoperiod consistently produced more leaves than did those grown under the 8- hr photoperiod.

**Spike development**

Under the 8- hr photoperiod, almost all in each PGR-treated plants developed spikes, whereas under the 24- hr treatment, those sprayed with SA, Uni, and the control developed spikes (Table 1). The percentage of plants that developed spikes was slightly decreased by the PDJ and significantly by GA. Under the 8- hr photoperiod, there were no differences as to node position of the first spikes among the PGR treatments and the control, and among the control, Uni, and PDJ treatments under the 24- hr photoperiod. But in the 24- hr photoperiod, the position of the first spikes was significantly higher in GA- and SA-sprayed plants. Between the same PGR treatments, the first spikes appeared at a higher node under the 24- hr photoperiod than comparable plants grown under the 8- hr photoperiod. Furthermore, the nodal position of the last spikes was highest in the control plants in both photoperiods and decreased with the following treatments: Uni, GA, SA, and PDJ. Whether PGR-treated or not, the nodal position of the last spikes was higher under the 24- hr photoperiod than those under the 8- hr photoperiod. Hence, the highest number of spikes per plant under both photoperiods was produced by the control plants followed in descending order by : Uni, GA, SA, and PDJ. Whether treated or not, the number of spikes per plant was greater under constant light than in the short day treatment.

The first spike was observed on 15 June, and the percentage of plants in each treatment that developed spikes increased and reached the maximum in early July (Fig. 3). At the onset of spike development, more spikes were initiated in plants grown under the 8- hr than under the 24- hr photoperiod. In GA-treated plants, not only was the emergence of spikes significantly delayed, but also fewer plants produced them. The percentage of plants that initiated spikes in the PDJ treatment was intermediate between those of the control and GA-treated ones.

**Aerial and new tuber development**

By the initial harvest on August 19, when the main shoots stopped growing in plants under the 8- hr photoperiod, aerial tubers were formed on the control, Uni, SA, and PDJ plants (Fig. 4). GA-treated plants failed to produce any aerial tubers. Likewise, no control and PGR-treated plants under the 24- hr photoperiod developed aerial tubers. The mean fresh of aerial tubers of the control and Uni-treated plants under the 8- hr photoperiod was heavier than those on plants sprayed with SA and PDJ. Under the 8- hr photoperiods, the heaviest new tubers were produced by the control plants followed successively lighter ones by those sprayed with GA, SA, PDJ, and Uni. Under the 24- hr photoperiod, PGR-treated plants produced equally small new tubers. Among comparably PGR-treated plants, the fresh
weight of new tubers under the 8-hr photoperiod was heavier than those under the 24-hr photoperiod. Hence, the total fresh weight of aerial and new tubers under the short day treatment was heavier than that under constant light.

By September 24, the main shoots stopped growing under the 24-hr photoperiod. The fresh weight of aerial tubers was heaviest in the untreated plants followed by successively lighter ones sprayed with PDJ and SA. Again, GA-treated plants failed to yield any aerial tubers. Among PGR-treated plants, the aerial tubers in plants grown under the 8-hr photoperiod were heavier than those on plants under the 24-hr photoperiod. Among the PGR treatments, those treated with GA yield the heaviest new tubers followed by those in the SA, control, PDJ, and Uni plants. The fresh weights of new tubers in plants grown under the 8-hr photoperiod in all treatments were heavier than those harvested from the 24-hr plots.

When dieback of main shoots occurred at the end of November for plants grown under the 8-hr photoperiod and in December for the 24-hr photoperiod, the fresh weight of aerial tubers had increased more than those harvested earlier. The largest yield was obtained from plants treated with Uni; successively lighter yields were harvested from PDJ, control, and SA plants. Again aerial tubers were not also observed in plants treated with GA. The fresh weight of aerial tubers increased significantly in plants grown under the 24-hr photoperiod since the previous harvest, but were similar to plants grown under the 8-hr photoperiod. Under the 8-hr photoperiod, GA-treated plants produced the heaviest new tubers, followed by PDI, SA, control, and Uni. In plants grown under the 24-hr photoperiod, the heaviest new tubers were also harvested from GA-treated plants, followed by the control, SA, and both Uni and PDJ treatments. Hence, the total fresh weights of aerial and new tubers under the 8-hr photoperiod were heaviest in plants treated with PDJ, followed by those from the control, Uni, and PDJ plots. Under the 24-hr photoperiod, the largest were obtained with GA, followed in descending order by: SA, control, Uni, and PDJ plots. Among all treatments and the control, the total fresh weights of aerial and new tubers under the 24-hr photoperiod was heavier than those under the 8-hr photoperiod.

Discussion

Shoot development

Main shoots growth was not enhanced by any PGR under 8- and 24-hr photoperiods. The leaf number of the main shoot was slightly decreased by GA treatment. These results indicate that the length of the internode was promoted by the GA treatment (data not shown). SA and PDJ treatment decreased the length and number of leaves on the main shoots, so that the length of the internode in the plant treated with SA and PDJ remained unchanged. Main shoots growth was decreased by Uni treatment, but did not decrease the number of leaves on the main shoots. This result indicates that the length of the internode was inhibited by Uni treatment.

Spike development

In previous experiments, the spike development of cv. Ichoimo was not changed significantly by day/night air and root zone temperatures, photoperiod, and seed tuber weight whether solo or combined (Yoshida et al., 1996; Yoshida and Kanahama, 1999; Yoshida et al., 1999;
Yoshida et al., 2000). In this experiment, the PGR tested also did not affect spike development in plants grown under the 8-hr photoperiod, but, spike development under the 24-hr photoperiod was severely inhibited by GA and slightly by PDI. The effects of gibberellin on flower induction in tuber and tuberosus root crops have been reported on taro plants (Colocasia esculenta Schott) (Matsumoto and Nakao, 1984; Katsura et al., 1986; Miyazaki et al., 1986). In these studies, gibberellin promoted flower induction.

The effects of PGR on the development of spikes in plants grown under the 24-hr photoperiod for unknown reason were greater than that on the plants under the 8-hr photoperiod.

**Aerial and new tuber development**

Aerial tubers are used for propagation of the Chinese yam cv. Ichoimo, but, at harvest time of the new tubers, aerial tubers drop and scatter around a field and eventually become weeds. GA-treatment would not only avoid this problem, but its suppression of aerial tubers would also growth of the new tubers by diverting the photosynthates which potentially could be utilized by the aerial tubers from the leaves to underground tubers.

Similarly, the formation of new tubers in greater yam (D. alata L.) plants was promoted by gibberellin (Onjo et al., 1997) and inhibited by anti-gibberellin [2-chloroethyl]trimethylammonium chloride (Ishihata et al., 1985). The promotion of the weight increase in new tubers by gibberellin treatment in greater yams (D. alata L.) is attributed to the inhibition of the vegetative growth (Onjo et al., 1997). This suggestion is supported by the results of our study.

That GA treatment might promote the start of new tubers development was verified by harvesting the new tubers just after the main shoots ceased elongating.

Although jasmonic acid is known to promote tuber growth in the potato or Chinese yam cv. Nagaimo (Koda and Kikuta, 1991; Koda, 1992; Takeuchi and Kamuro, 1997) plants, it had no effect in this experiment. Salicylic acid, an antagonist of jasmonic acid (Pena-Cortes et al., 1993; Seo et al., 1997), did not suppress the development of new tubers in Chinese yam cv. Ichoimo.

**Literature Cited**


‘イチョウイモ’の花穂と新茎の発育に及ぼす日長と植物生長調整物質の組み合わせ処理の影響

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摘 要

‘イチョウイモ’の主枝、花穂、むかごおよび新茎の発育に及ぼす日長と、ジベレリン100 ppm (GA区)、ウニコナゾール25 ppm (Uni区)、ジャスモン酸誘導体50 ppm (PDJ区)、またはサリチル酸1000 ppm (SA区)との組み合わせ処理の影響について調べた。主枝の発育は、对照区、GA区、SA区、PDJ区の順で促進され、Uni区は著しく抑制された。植物生長調整物質の影響は、8時間日長よりも24時間日長との組み合わせ処理によって大きくなった。花穂の発育した個体の割合は、8時間日長よりも24時間日長とGAとの組み合わせ処理によって著しく抑制された。第1花穂着生節位は8時間日長より24時間日長で高くなったが、植物生長調整物質による違いは明瞭でなかった。1株当たり花穂数は8時間日長よりも24時間日長で多く、いずれの日長でもGA区で著しく減少した。むかごと新茎の初期の発育は8時間日長区で24時間日長区より早く、最終の発育量は逆に、24時間日長区で大きくなった。むかごの発育は、いずれの日長でもGA区で著しく抑制され、Uni区で促進された。新茎の発育はGA区で著しく促進され、Uni区で著しく抑制された。PDJとSAではむかごと新茎の発育に及ぼす影響は明瞭でなかった。