Parthenocarpic Fruit Set and Endogenous Indole-3-acetic Acid Content in Ovary of *Cucumis sativus* L.

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Summary

The relationship between parthenocarpic fruit set and endogenous indole-3-acetic acid (IAA) content in ovaries of the cucumber, 'Chojitsu-Ochiai No. 2', a strongly parthenocarpic cultivar, and 'PMR-142', a weakly parthenocarpic cultivar, was studied. All ovaries after reaching 6 cm in length grew steadily thereafter to set parthenocarpic fruits. Some ovaries of 'Chojitsu-Ochiai No. 2' reached this critical length on day 3 after anthesis. In 'PMR-142', more female flowers at higher nodes and with longer ovaries set parthenocarpically than did those at lower nodes bearing shorter ovaries. The enzyme-linked immunosorbent assay (ELISA) detected 3.5 times more IAA in the ovaries which were predicted to set parthenocarpically than in the ovaries which were not. The assay in 'Chojitsu-Ochiai No. 2' on day 3 after anthesis showed that ovaries longer than 6 cm which were predicted to set parthenocarpically contained 1.7 times more IAA than did those shorter than 6 cm. The results indicate a positive relationship between the endogenous IAA level in ovaries and the parthenocarpic fruit set in the respective cultivars.

Introduction

Fruit set normally requires fertilization which triggers synthesis of growth substances in ovules which are then exported to the ovary wall. Plants of many genera, however, possess the ability to set fruit without fertilization. Such parthenocarpic fruit set is considered to be stimulated by high concentration of endogenous growth substances in the ovaries (7). It has been observed that the endogenous level of growth substances, such as auxin, is higher in ovaries of parthenocarpic cultivars than in those of non-parthenocarpic cultivars (6). The most important growth substance in the parthenocarpic fruit set of cucumber may be auxin, as exogenously applied auxins and auxin transport inhibitors induce parthenocarpic fruit set (1, 2, 4, 12, 13, 14, 15, 18). Although a high concentration of auxin in the ovary is reported to be essential for the parthenocarpic fruit set in cucumber (1), we found no obvious difference in endogenous IAA levels in ovaries of parthenocarpic and non-parthenocarpic cultivars (17). Different cultivars may have different endogenous auxin levels, irrespective of the parthenocarpic intensity. Therefore, the endogenous auxin level should be compared between ovaries which have the potential to set parthenocarpically and those which do not within a given cultivar. It is difficult to determine, however, which ovary will set parthenocarpically; and, therefore, no report has been published to that effect. Another problem is that previous estimations of auxin have been done mostly with bioassay (7). Accordingly, the present work was aimed to seek indicators which would measure the potential of an ovary to set parthenocarpically, and quantify the endogenous IAA content in ovaries which would and would not set parthenocarpically. For this purpose the ELISA (19) which yields results as accurate as the analysis by gas chromatography-mass spectrometry (3, 16) was used.

Materials and Methods

1. Plant materials

Cucumber 'Chojitsu-Ochiai No. 2' (monoecious) and 'PMR-142' (gynoecious) were used as ex-
experimental materials. Seeds were planted in plastic pots in early April and the seedlings were transplanted to a glasshouse in late April in 1989 and 1990. Female flowers which formed at nodes 6 to 30 of the main stem and bloomed between June and August were used. Each flower was covered with a paper bag the day prior to anthesis to prevent natural pollination. Lengths of individual ovaries were measured daily following anthesis as a parameter of the growth (5). The measurements were continued until the fruits were harvested; 'PMR-142' and 'Chojitsu-Ochiai No. 2' were 10 and 20 cm length, respectively. Five plants per cultivar were used.

2. Analysis of IAA

Ovaries were harvested at anthesis or 3 days later. The sample was immediately extracted and the extract purified, and the endogenous IAA in it was quantified by ELISA as previously described (17).

Results and Discussion

1. Factors influencing parthenocarpic fruit set

The growth patterns of the ovaries of all female flowers formed on a plant were classified into two distinct groups (Figs. 1 and 2). Namely, there were ovaries which grew rapidly and those which ceased growing and shriveled following several days of normal growth after anthesis. The former was considered to have set and the latter had not. Some of the ovaries which failed to set grew to some extent but they never reached 6 cm. On the other hand, all ovaries which attained 6 cm in length grew well and set. Fast growing ovaries of 'Chojitsu-Ochiai No. 2' reached this critical length on day 3 after anthesis.

The growth kinetics (Figs. 1 and 2) suggested a possible relationship between the position of the node at which the female flower was born and the potential of its ovary to set a parthenocarpic fruit. Higher percent fruit set was observed at higher nodes, particularly by ovaries located at nodes higher than 26 in 'PMR-142' (Table 1).

![Fig. 1. Time course of elongation in ovary of Cucumis sativus 'PMR-142'. Length of the ovary of flower formed at each node (small numeral in the figure represents position of the node on the main stem) was measured daily starting on the day of anthesis (indicated with a large closed circle) until it became longer than 10 cm.](image)
Ovaries at nodes lower than 25 have the potential to develop because between 70 and 80% of them set fruits, provided they were pollinated (data not shown). Percent fruit set was quite high in 'Chojitsu-Ochiai No. 2', and the difference in the potential for parthenocarpic fruit set among nodes was unclear.

The growth kinetics also indicated that the ovaries at higher nodes were longer at anthesis, particularly in 'PMR-142'. Thus a possible relationship between the ovary length and the potential for parthenocarpic fruit set exists. The percent fruit set in 'PMR-142' was higher in the ovaries whose length at anthesis exceeded 3.0 cm than in the ovaries which were shorter (Table 2). The same tendency was also found in 'Chojitsu-Ochiai No. 2' but the difference in percent fruit set between the long and short ovaries was quite small.

From these data it is possible to predict that at anthesis, female flowers of 'PMR-142' that formed

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**Table 1.** Percent parthenocarpic fruit set of flowers formed at different nodes of the main stem in *Cucumis sativus* 'PMR-142' and 'Chojitsu-Ochiai No. 2'.

<table>
<thead>
<tr>
<th>Node</th>
<th>PMR-142</th>
<th>Chojitsu-Ochiai No. 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>6–10</td>
<td>6.9</td>
<td>84.6</td>
</tr>
<tr>
<td>11–15</td>
<td>13.8</td>
<td>100</td>
</tr>
<tr>
<td>16–20</td>
<td>20.7</td>
<td>100</td>
</tr>
<tr>
<td>21–25</td>
<td>24.1</td>
<td>100</td>
</tr>
<tr>
<td>26–30</td>
<td>88.5</td>
<td>-2</td>
</tr>
</tbody>
</table>

* No mature female flower was formed at these nodes.

**Table 2.** Percent parthenocarpic fruit set of flowers which had ovaries of different length at anthesis in *Cucumis sativus* 'PMR-142' and 'Chojitsu-Ochiai No. 2'.

<table>
<thead>
<tr>
<th>Ovary length (cm)</th>
<th>PMR-142</th>
<th>Chojitsu-Ochiai No. 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.9</td>
<td>13.5</td>
<td>-2</td>
</tr>
<tr>
<td>2.0–2.9</td>
<td>8.6</td>
<td>-</td>
</tr>
<tr>
<td>3.0–3.9</td>
<td>48.6</td>
<td>93.1</td>
</tr>
<tr>
<td>4.0–4.9</td>
<td>-2</td>
<td>100</td>
</tr>
<tr>
<td>5.0</td>
<td>-</td>
<td>100</td>
</tr>
</tbody>
</table>

* All the ovaries examined were shorter than 3.9 cm in 'PMR-142' and longer than 3.0 cm in 'Chojitsu-Ochiai No. 2'.

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![Fig. 2.](image-url) Time course of elongation in ovary of *Cucumis sativus*, 'Chojitsu-Ochiai No. 2'. Length of ovaries was measured as in Fig. 1 but until they became longer than 20 cm. No mature female flower was formed at the nodes for which numerals are not shown in the figure.
at higher nodes and had longer ovaries would set parthenocarpically. The present result agrees with the reports that female squash and cucumber flowers with large ovaries produced by older plants develop parthenocarpically (8, 9, 10).

2. Endogenous IAA level in ovary

The female flowers of 'PMR-142' which formed between nodes 11 and 15 had ovaries of about 2 cm in length, whereas those which formed from nodes 26 to 29 had ovaries 3-cm long at anthesis. It is statistically predictable that longer ones would set parthenocarpically, whereas the shorter would not. When the respective ovaries were extracted and the endogenous IAA quantified by ELISA, the long ovaries contained 3.5 times more IAA than the short ovaries (Table 3).

For 'Chojitsu-Ochiai No. 2', it was difficult to predict at anthesis which ovary would set parthenocarpically. On day 3 after anthesis, however, it was possible to determine that the ovaries which were longer than 6 cm would set parthenocarpically. Accordingly, the 3-day-old female flowers were harvested regardless of the node position; the endogenous IAA content in the ovaries longer than 6 cm were compared with those which were shorter (Table 4). The longer ovaries contained 1.7 times more IAA than the shorter ones. The shorter ovaries analyzed may have included not only ovaries which would not set but also those which would have set but their growth was merely delayed. Therefore, the actual difference in the endogenous IAA levels between ovaries which will and will not set parthenocarpically may be much larger.

Ovaries of cultivars that set parthenocarpic fruit have been assumed to contain a higher level of auxin at anthesis than ovaries of cultivars that require fertilization for fruit growth (10). In the present study, however, we detected less endogenous IAA in ovaries of 'Chojitsu-Ochiai No. 2' than in ovaries of 'PMR-142'. Although IAA was quantified on different days after anthesis in these 2 cultivars, we have previously shown that ovaries of a non-parthenocarpic cultivar, 'Mogami', contained the same IAA level as ovaries of 'Chojitsu-Ochiai No. 2' at anthesis (17). It was suggested that the level of endogenous IAA triggering the parthenocarpic fruit set might differ in different cultivars of cucumber (8). Therefore, the difference in endogenous IAA levels between different cultivars is insufficient to establish a clear relationship between the IAA level and the potential to set parthenocarpic fruit. In this study we examined the IAA level within a cultivar and found that in 'PMR-142' a clear difference existed between ovaries which were and were not predicted to set parthenocarpically. The same difference was observed in 'Chojitsu-Ochiai No. 2'. Our results are consistent with those reported by Kim et al. (9). We, therefore, conclude that, within a cultivar, the ovaries which contain a higher level of IAA at anthesis can set parthenocarpically whereas those with low IAA content cannot. Among different cultivars, however, the positive relationship between the endogenous IAA level and the potential for parthenocarpic fruit set is not always observed. Possible involvement of endogenous cytokinins (11) or other unknown factors in parthenocarpy has to be considered.

### Table 3. Endogenous IAA level at anthesis in ovaries of different lengths at basal and distal nodes in Cucumis sativus 'PMR-142' as detected by ELISA.

<table>
<thead>
<tr>
<th>Node</th>
<th>Ovary length (cm)</th>
<th>ng IAA/g FW of tissue eq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>11−15</td>
<td>1.9−2.1</td>
<td>44.8 ± 0.928</td>
</tr>
<tr>
<td>26−29</td>
<td>3.0−3.3</td>
<td>157 ± 8.08</td>
</tr>
</tbody>
</table>

Each value is mean of 3 assays ± SE for nodes 11−15 and mean of 5 samples ± SE for nodes 26−29.

### Table 4. Endogenous IAA level in ovaries of different length in Cucumis sativus 'Chojitsu-Ochiai No. 2' as detected by ELISA on day 3 after anthesis.

<table>
<thead>
<tr>
<th>Ovary length (cm)</th>
<th>ng IAA/g FW of tissue eq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;6</td>
<td>69.9 ± 2.59</td>
</tr>
<tr>
<td>6±</td>
<td>119 ± 9.78</td>
</tr>
</tbody>
</table>

Each value is mean of 3 assays ± SE.

* The datum is the same as reported previously (17).

### Literature Cited


キュウリの単為結果と子房の内生インドール-3-酢酸レベルの関係

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摘 要

キュウリ、‘長日落合 2 号’と‘PMR-142’の受粉しない子房の生長を連続的に測定した。一部の子房は開花後しばらく生長を続けた後に生長を停止したが、子房の長さが6 cm を越えたものは、その後も引続き生長を続けて単為結果に至ることが見出された。‘長日落合 2 号’では、早いものでは開花 3 日後にこの長さに達したので、開花 3 日後にはどの子房が単為結果するかを予測することができた。‘PMR-142’では、高位の節に形成された子房の長い離花は、低位の節に形成された子房の短い離花よりも高い率で単為結果した。このことから、‘PMR-142’では、どの子房が単為結果するかを開花した日に予測することができた。単為結果すると予測された子房と、単為結果しない予測された子房の開花した日の内生インドール-3-酢酸 (IAA) レベルを酵素イムノアッセイによって定量した。‘PMR-142’では、単為結果すると予測された子房で単為結果しないと予測された子房より3.5倍高い IAA 含量が検出された。一方、開花 3 日後の子房の長さに基づいて単為結果するかしないかを予測した‘長日落合 2 号’の子房では、単為結果すると予測された子房で1.7倍高い IAA 含量が検出された。これらの結果から、それぞれの品種において、開花時における内生 IAA レベルの高い子房が単為結果するものと推測された。