EFFECTS OF PLANT GROWTH REGULATORS ON LATERAL SHOOT BRANCHING OF BROCCOLI.

Yukihiro Fujime and Tadahiko Hirose

Effects of five plant growth regulators on formation and development of branching were investigated for broccoli variety 'Wase-Midori' and 'Green-18', which were different in branching property.

1. The terminal curd weight of Wase-Midori was not affected by the growth regulators, but the increased lateral shoot weight was pronounced in the benzyladenine, ethephon, morphactin and TIBA plots.

2. Effects of the growth regulators on the terminal curd weight of Green-18 were not recognized but the increased weight of lateral shoots was slightly smaller in the morphactin plot but larger in the TIBA plot, compared with the control.

3. Mean weight of a lateral shoot of Wase-Midori was not affected by the growth regulators but the increased number of lateral shoot per plant increased in the benzyladenine, ethephon, morphactin and TIBA treatments, notably by benzyladenine.

4. Mean weight of a lateral shoot of Green-18 was not affected by the growth regulators but the increased number of lateral shoot per plant was slightly smaller in the morphactin plot.

5. Terminal curd weight of Wase-Midori was not affected by the treatment with benzyladenine. But the increased lateral shoot weight was more pronounced parallel with the concentration of benzyladenine.

6. Though mean weight of a lateral shoot of Wase-Midori was not affected with benzyladenine, the higher the concentration of benzyladenine, the more the number of lateral shoot per plant increased.

分枝特性の異なる‘早生緑ハナヤサイ’と’Green-18’を用い，側枝の発育に及ぼす生長調節物質の影響を調べた。

1. 早生緑の頂花らい重に対する生長調節物質の影響は認められなかったが，側枝重はペンジルアデニン，エセフォン，モルファクチン，TIBA処理により増加した。

2. Green-18 の頂花らい重に及ぼす生長調節物質の影響は認められなかったが，側枝重はモルファクチン処理で減少し，TIBA処理で増加した。

3. 生長調節物質処理の早生緑の平均側枝重に対する影響は認められなかったが，ペンジルアデニン，エセフォン，モルファクチン，TIBA処理では，株あたりの側枝数は増加した。

4. Green-18 の平均側枝重に生長調節物質処理の影響は認められなかったが，株あたりの側枝数はモルファクチン
Introduction

There are some reports on chilling requirement in curd formation of broccoli as well as cauliflower (5, 7, 11, 29). General properties of broccoli in growing is very similar to that of cauliflower, but there are some obvious differences between both plants in internodal elongation, flower bud development and branching. Lateral shoot branching of cauliflower is not seen commonly because of its strong apical dominance. But the lateral shoot branching of broccoli is vigorous.

So far as we are aware, only one report is available about the acceleration of the growth and development of lateral shoots of broccoli after the terminal curd formation (22). But the relation of branching property in broccoli and earliness is yet obscure. Only terminal curds are ordinary harvested in extremely-early broccoli varieties, but terminal curds and lateral shoots are harvested in early, medium or late varieties. Hand pinching of broccoli plant apices leads to high yields of side shoots (16, 17).

In this study, effects of five growth regulators on branching promotion and later development were investigated, using two varieties of different branching property.

Materials and Methods

Experiment I. A moderate apical dominance variety, 'Wase-Midori' and a weak apical dominance variety, 'Green-18' were seeded in sowing bed on March 16, 1972 in a greenhouse maintaining a minimum night temperature of 20°C from March 16 to April 27. After the 3rd leaf opened, the plant was transplanted to a 8 cm jiffy pot on April 6, planted in open field on April 27 when the 8th leaf opened and cultivated as usual.

The five growth regulators, kinetin (50 ppm), benzyladenine (50 ppm), ethephon (500 ppm), morphactin (10 ppm) and 2,3,5-triiodobenzoic acid (TIBA; 100 ppm) were dissolved in distilled water containing a 0.5% tween-20. The solution (30 ml) was sprayed with a hand sprayer onto an entire plant twice on June 5 and June 10, when the terminal curd was budded. The solution containing no growth regulator was served as control. Leaf number, stem length, curd diameter and lateral shoot number were measured at the time when the plants were treated with the solution. Growth and development of plant were recorded at curd maturation. Lateral shoots, being over 15 cm long and 10 g weigh, were harvested from June 15 to 30 days after the average maturing date.

Experiment II. Varieties used in this experiment were the same as above and were seeded in sowing bed on March 29, 1973 in a greenhouse maintaining a minimum night temperature of 20°C from March 29 to April 30. The plant was transplanted to April 16, planted in open
field on April 30 and cultivated as usual.

The entire plant was sprayed with 30 ml of 0, 10, 50 and 100 ppm benzyladenine by a hand sprayer twice on May 25 and May 30, when the terminal curd is presumably formed. The growth and development were recorded at curd maturity and lateral shoots were harvested from June 23 to 20 days after the average maturing date.

Results

Experiment I. The stem length, leaf number, curd diameter and lateral shoot number of Wase-Midori and Green-18 were similar among the experimental plots at the spraying time (Table 1.). Lateral shoot number of Wase-Midori was from five to eight and the number of Green-18 was about ten.

Table 1. Stem length, leaf number, curd diameter and lateral shoot number per plant at treatment.

<table>
<thead>
<tr>
<th>Variety 'Wase-Midori'</th>
<th>Growth regulators</th>
<th>Stem length per plant</th>
<th>Leaf number per plant</th>
<th>Curd diameter cm</th>
<th>Lateral shoot number per plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>31.4±2.2*cm</td>
<td>23.0±0.8*</td>
<td>5.8±2.8*cm</td>
<td>5.4±2.6*</td>
<td></td>
</tr>
<tr>
<td>Kinetin 50 ppm</td>
<td>30.6±2.9</td>
<td>23.1±2.3</td>
<td>4.8±3.0</td>
<td>5.5±3.8</td>
<td></td>
</tr>
<tr>
<td>Benzyladenine 50</td>
<td>31.8±1.7</td>
<td>23.9±1.1</td>
<td>5.5±1.0</td>
<td>6.3±1.4</td>
<td></td>
</tr>
<tr>
<td>Ethephon 500</td>
<td>29.6±0.7</td>
<td>23.4±0.9</td>
<td>4.9±1.1</td>
<td>7.6±1.7</td>
<td></td>
</tr>
<tr>
<td>Morphactin 10</td>
<td>29.4±1.4</td>
<td>23.0±1.2</td>
<td>4.8±1.9</td>
<td>6.9±1.3</td>
<td></td>
</tr>
<tr>
<td>TIBA 100</td>
<td>30.3±1.5</td>
<td>24.5±1.1</td>
<td>5.1±1.6</td>
<td>5.8±2.2</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variety 'Green-18'</th>
<th>Growth regulators</th>
<th>Stem length per plant</th>
<th>Leaf number per plant</th>
<th>Curd diameter cm</th>
<th>Lateral shoot number per plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>28.3±1.7*cm</td>
<td>24.4±2.0*</td>
<td>2.6±0.9*cm</td>
<td>10.1±1.2*</td>
<td></td>
</tr>
<tr>
<td>Kinetin 50 ppm</td>
<td>29.0±2.0</td>
<td>23.1±1.7</td>
<td>2.1±1.0</td>
<td>10.1±3.1</td>
<td></td>
</tr>
<tr>
<td>Benzyladenine 50</td>
<td>27.6±1.1</td>
<td>22.9±1.3</td>
<td>2.4±1.0</td>
<td>10.8±2.0</td>
<td></td>
</tr>
<tr>
<td>Ethephon 500</td>
<td>28.6±1.1</td>
<td>23.0±2.0</td>
<td>1.7±1.0</td>
<td>10.0±2.4</td>
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</tr>
<tr>
<td>Morphactin 10</td>
<td>27.9±1.0</td>
<td>22.8±1.7</td>
<td>1.9±0.5</td>
<td>10.5±1.0</td>
<td></td>
</tr>
<tr>
<td>TIBA 100</td>
<td>28.8±1.0</td>
<td>23.3±1.1</td>
<td>1.9±0.7</td>
<td>10.9±1.5</td>
<td></td>
</tr>
</tbody>
</table>

* Confidence limit (95%)
Effects of growth regulators on weight of terminal curd and lateral shoots of 'Wase-Midori' and 'Green-18'.

The weight of terminal curd and lateral shoots of Wase-Midori and Green-18 at 10 days after the treatment with the growth regulators are shown in Fig. 1. There were no significant difference in weight of terminal curd of Wase-Midori between the control and treatments, except in the ethephon plot in which the weight was slightly smaller. The increase in lateral

![Diagram showing effects of growth regulators on weight of terminal curd and lateral shoots.](image-url)
shoot weight was more pronounced in all treatment plots except the kinetin plot: the increase was notable in the benzyladenine plot, while kinetin treatment had no effect. The increased curd weight of Green-18 in the ethephon plot was slightly smaller than the control, but was similar in the other four plots. The increased weight of lateral shoots was slightly smaller in the morphactin plot but larger in the TIBA plot, compared with the control.

Figure 2 shows the mean weight and number per plant of lateral shoot of Wase-Midori. Mean weight was slightly smaller in the ethephon, morphactin and TIBA plots. The increase in the lateral shoot number was accelerated by the treatment with benzyladenine, ethephon, morphactin and TIBA. Thus, the increase in total weight of lateral shoots is attributable to the increased number of lateral shoot.

![Graph showing the effects of growth regulators on mean lateral shoot weight and lateral shoot number per plant of 'Green-18'.](image)

Mean weight and number of lateral shoot of Green-18 are shown in Fig. 3. Mean weight was not affected by the treatment with the growth regulators and the number was slightly fewer in the morphactin plot than the other plots. In the ethephon plot, abnormal flower bud development was observed and curd development was accelerated and flowered earlier than other plots.

**Experiment II.** Figure 4 shows the weight of terminal curd and lateral shoots of Wase-Midori and Green-18. Terminal curd weight of Wase-Midori was not affected by the treatment with benzyladenine, but the higher the concentration of benzyladenine, the more lateral shoot weight increased. No effect of benzyladenine was observed for Green-18.

Mean weight and number of lateral shoot per plant of Wase-Midori and Green-18 are shown in Fig. 5. Mean lateral shoot weight of Wase-Midori was not affected by the treatment with
Fig. 4. Effects of benzyladenine on weight of terminal curd and lateral shoots.

Fig. 5. Effects of benzyladenine on mean lateral shoot weight and lateral shoot number per plant.
benzyladenine, but the increased number of lateral shoots was more pronounced parallel with the concentration of benzyladenine. The effect of benzyladenine was not observed for Green-18.

Curd diameter and height of Wase-Midori and Green-18 at maturity was not affected by the treatment with benzyladenine (Table 2).

Table 2. Effects of benzyladenine on diameter and height of terminal curd.

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Benzyladenine</th>
<th>Curd diameter</th>
<th>Curd height</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 ppm</td>
<td>21.4±2.9*cm</td>
<td>17.3±1.4*cm</td>
</tr>
<tr>
<td>'Wase-Midori'</td>
<td>10</td>
<td>22.6±1.3</td>
<td>18.1±1.2</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>22.7±2.3</td>
<td>19.0±0.9</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>23.2±1.1</td>
<td>20.0±1.1</td>
</tr>
<tr>
<td>'Green-18'</td>
<td>0</td>
<td>17.4±1.7</td>
<td>17.5±1.3</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>15.0±1.4</td>
<td>15.7±0.9</td>
</tr>
</tbody>
</table>

* Confidence limit (95%)

Discussion

The results of the experiment presented in this paper indicate that benzyladenine promoted the lateral shoot branching of Wase-Midori without inhibiting the growth and development of terminal curd, providing the increased yields of lateral shoots.

Since many horticultural plants such as carnation, chrysanthemum and strawberry are propagated with vegetatively, their vigorous branching are needed. The yields of broccoli, carnation, eggplant, pea, poinsettia, rose and others depend on their apical dominance. Apical dominance is also attached importance to regulate the form of garden plants.

THIMANN and SKOOG showed that auxin applications can replace the stem apex in inhibiting the growth of lateral buds. SACHS and THIMANN reported that cytokinins break the apical dominance. Since then there have been many reports to bring together the concept of these hormonal action and nutritive action on apical dominance.

Some other growth regulators also play a role in apical dominance and many trials have been made to use growth regulators such as cytokinin, ethephon, gibberellin, morphactin and TIBA in practical growing.

In the present experiments, benzyladenine, ethephon, morphactin and TIBA also promoted the lateral shoot branching. By the ethephon treatment, curd maturation as well as branching were promoted. Promotion of maturation is well-known as ethylene action. ZIESLIN et al. also reported the abnormal development of roses.

In the present work, abnormal development of curd was not recognized in plants treated with morphactin and TIBA. The promotion of branching by these growth regulators was not
so intenser, compared with the benzyladenine plot. This is probably due to the differences in mode of action among the regulators, in term of competing with auxin and affecting auxin-transport (9, 38).

Benzyladenine promoted the branching in proportion to increasing concentration without inhibiting the growth of terminal curd, however. Benzyladenine is one of the principal synthetic cytokinins and its activity seems to be higher than kinetin (38). The branching was not promoted by the treatment with kinetin in this experiment, perhaps because of its low concentration.

It is well-known that cytokinins not only overcome the auxin suppression of lateral buds but also have the retarding effect of senescence and promoting effect of translocation. Sorokin and Thimann (31) stated that cytokinins stimulated the vascular development connecting the lateral with the main vascular system serving to relieve the nutrient shortage in the lateral buds. Acceleration of flowering with benzyladenine is also reported by Thomas (25) in the promotion of lateral bud development and flowering of Brussels sprouts. Hewett and Wareing (36) indicated that cytokinin contents increase during chilling and bud burst.

The reproductive growth of cold-requiring plants seems to be promoted after the chilling requirement has been satisfied fully (3). The authors previously reported that the weight of terminal curd and lateral shoots increased with seed-vernialization (4). The promotion of lateral shoots: branching by benzyladenine might be due to the overcoming effect of this chemical in the branching inhibition and following promotion effect of their development.

The effects of growth regulators on branching highly differed between the two varieties. The branching of Wase-Midori, a moderate apical dominance variety, was promoted but that of Green-18, a weak apical dominance variety, was not promoted moreover. Nakamura (35) reported that early and late pea varieties respond to external factors such as growth regulator, photoperiod and temperature differently to each other. Though branching habit is primarily genetically determined, external factors also affect it. To promote the branching of a weak apical dominance variety moreover, other factors besides growth regulators should be considered.

Acknowledgement

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