[Short report]

Effects of Gibberellic Acid Application on Panicle Characteristics and Size of Shoot Apex in the First Bract Differentiation Stage in Rice

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Key words: GA₃, Gibberellic acid, Panicle, Rachis branch, Rice, Shoot apical meristem, Spikelet.

The number of spikelets in a panicle is an important factor in determining the yield of rice. Spikelet differentiation in a panicle is stimulated by gibberellic acid applied at the spikelet differentiation stage (Shimizu, 1965; Shimizu et al., 1966; Kawai et al., 1989; Matsuba, 1991; Yamagishi et al., 1994). Matsuba (1991) mentioned that the observation of fully branched panicles treated with gibberellicin would be necessary to understand the potential of panicle growth.

The effect of gibberelic acid may be attributed to the increase in cell division in the shoot apical meristem (SAM) at the spikelet differentiation stage. Therefore, we examined the effect of applied gibberellic acid (GA₃) on SAM at the first bract differentiation stage microscopically and its relation to the panicle characteristics.

Materials and Methods

Two rice varieties (Oryza sativa L. var. Nipponbare and Akenohoshi) were seeded in nursery boxes on April 22, 2000, and 16 seedlings per pot (1/2000 a) were transplanted on May 20. Tillers were removed and only the main stems were left intact. Compound fertilizer (N : P₂O₅ : K₂O = 12 : 18 : 16%) was applied; 7 g as basal fertilizer and 10 g as topdressing fertilizer two times, June 23 (before panicle initiation stage) and August 10 (after heading). Heading dates of both varieties were August 9 irrespective of GA₃ treatment. GA₃ was dissolved in distilled water at a concentration of 50 ppm, and 30 mL of this solution per pot was sprayed to the plants on June 23 and 25. Shoot apices were taken at around the first bract differentiation stage, and fixed in FAA, dehydrated in t-butyl alcohol series and embedded in Paraplast Plus (Oxford Labware, U.S.A.). The median longitudinal sections with the thickness of 10 μm were prepared and stained with safranin, iron-tannic acid and orange G. Three shoot apices at exactly the late stage of the first bract differentiation were chosen for observation. The shoot apex at this stage had the first bract primordium with 7 to 10 layers of cells. The diameter and the number of cells at the base of the apical dome (SAM) were measured just above the primordium of the first bract.

The volume and the number of cells in the SAM were calculated using the following formula assuming the dome of SAM as approximate to a half ellipsoid (Smith et al., 1979).

\[ V = \frac{2}{3} \pi r^2 h \]

Where \( v \) = volume or cell number, \( r \) = basal radius or cell number along the radius and \( h \) = height or cell number along the height.

Four panicles were harvested at the matured stage and the numbers of rachis branch and spikelet counted. The reduced rachis branches and spikelets were estimated from the vestiges and the empirical observations of the similarities of the adjacent rachis branches or spikelets. The number of differentiated rachis branches or spikelets was the sum of viable and reduced organs.

Results and Discussion

The effects of GA₃ application on the number of rachis branches and spikelets per panicle are shown in Table 1. The effects were different in Nipponbare and Akenohoshi. In Nipponbare, the number of differentiated primary rachis branches and spikelets on the primary rachis branch was increased 60.9 and 48.1%, respectively, by the application of GA₃, though the number of the differentiated second rachis branches and spikelets on the second rachis branch was reduced 36.2 and 43.4%, respectively. Therefore, the total number of differentiated spikelets on the panicle treated with GA₃ was similar to that in the control. In Akenohoshi, the GA₃ induced increase in the number of differentiated primary rachis branches and spikelets on the primary rachis branch, 92.3 and 72.7%, respectively, was accompanied by less reduction in the number of differentiated second rachis branches and spikelets on the second rachis branches. Therefore, the total number of differentiated spikelets on a panicle treated with GA₃ was 13.5% higher than that in the control although the standard error was large.

Although the number of primary rachis branches and spikelets on the primary rachis branches was increased by GA₃ treatment in both varieties, the rate of increase was higher in Akenohoshi. This varietal difference in the
Table 1. The effect of applied GA₃ on panicle characteristics, the number of rachis branches and spikelets in a panicle. GA₃ solution (50 ppm) was sprayed twice before panicle initiation.

<table>
<thead>
<tr>
<th>Variety</th>
<th>GA₃ Concentration (ppm)</th>
<th>Primary Rachis Branch Number</th>
<th>Secondary Rachis Branch Number</th>
<th>Spikelet Number in a Panicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nipponbare</td>
<td>0</td>
<td>11.5±0.6</td>
<td>64.8±3.9</td>
<td>24.3±2.1 69.8±4.8 133.8±6.1</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>18.5±1.0</td>
<td>96.0±6.1</td>
<td>15.6±2.4 39.5±3.8 135.6±3.1</td>
</tr>
<tr>
<td>Akebonoishi</td>
<td>0</td>
<td>14.3±1.0</td>
<td>81.8±3.0</td>
<td>61.8±2.8 215.8±10.1 297.5±8.3</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>27.5±5.2</td>
<td>141.3±31.2</td>
<td>59.3±11.3 196.5±37.3 337.8±24.0</td>
</tr>
</tbody>
</table>

Values are means±standard error.

Table 2. The effect of applied GA₃ on the size of shoot apical meristem (SAM) and the cell. GA₃ solution (50 ppm) was sprayed twice before panicle initiation.

<table>
<thead>
<tr>
<th>Variety</th>
<th>GA₃ Concentration (ppm)</th>
<th>Diameter of SAM (μm)</th>
<th>Height of SAM (μm)</th>
<th>Volume of SAM (μm³×10⁶)</th>
<th>Width of cell (μm)</th>
<th>Height of cell (μm)</th>
<th>Total number of cells in median longitudinal section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nipponbare</td>
<td>0</td>
<td>110.3±6.4</td>
<td>50.5±2.5</td>
<td>3.23±0.04</td>
<td>7.7±0.5</td>
<td>5.6±0.6</td>
<td>97.7±3.9</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>111.1±6.7</td>
<td>63.1±5.1</td>
<td>4.10±0.63</td>
<td>7.6±0.4</td>
<td>7.0±0.3</td>
<td>108.7±15.9</td>
</tr>
<tr>
<td>Akebonoishi</td>
<td>0</td>
<td>122.0±3.9</td>
<td>58.1±6.7</td>
<td>4.55±0.78</td>
<td>7.8±0.6</td>
<td>6.5±0.2</td>
<td>108.0±19.7</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>144.8±6.4</td>
<td>106.9±10.2</td>
<td>11.78±1.82</td>
<td>8.4±0.4</td>
<td>8.5±0.6</td>
<td>194.7±11.9</td>
</tr>
</tbody>
</table>

Values are means±standard error.

Fig. 1. The effect of GA₃ application on SAM at the late first bract differentiation stage in var. Nipponbare. A: Control. B: Treated with 50 ppm GA₃ twice before the panicle initiation stage. B1: The first bract primordium. Bar in each figure shows 50 μm.

Fig. 2. The effect of GA₃ application on SAM at the late first bract differentiation stage in var. Akebonoishi. A: Control. B: Treated with 50 ppm GA₃ twice before the panicle initiation stage. B1: The first bract primordium. Bar in each figure shows 50 μm.

Sensitivity to GA₃ was also observed previously (Yamagishi et al., 1994), and requires further study.

The effects of GA₃ on the size and the number of cells in SAM at the late stage of the first bract differentiation are shown in Table 2, and photographs in Figs. 1 and 2. The effects were different in Nipponbare and Akenoishi. In Nipponbare, both the volume and height of SAM showed 25% increase by GA₃ application, although the diameter was not affected. The mean lengths of cell along the diameter and height in SAM were not affected by GA₃ application. Therefore, the increase in the height of SAM is not attributed to the increase in cell size, but to the increase in the number of cells along the height. On the other hand, in Akenoishi, both the diameter and height of SAM were increased 18.7 and 84.0%, respectively, by GA₃ treatment, and the volume of SAM was increased by 158.9%. Though the cell lengths along the height of SAM was increased by GA₃ in Akenoishi, the increase in the height of SAM by GA₃ was mainly due to the increase in the number of cells rather than the
increase in the size of cells. It is known that gibberellic acid promotes the longitudinal growth due to both cell elongation and cell division (Shimizu, 1965). In our study, the increase in height of SAM was mainly caused by the increase in the number of cells in both varieties.

The number of spikelets in a panicle has been reported to be positively related to the diameter of SAM (Yamagishi et al., 1992; Fukushima, 1999) among the rice varieties. Fukushima (1999) also pointed out a close correlation between the number of primary rachis branches and the diameter of SAM, and mentioned that the number of differentiated primary rachis branches was limited by the space. We have reported the close correlation between the number of primary rachis branches and the volume of SAM among five rice varieties at the flag leaf and the first bract differentiation stages (Mu et al., 2000). Therefore, the increase in the number of the primary rachis branches by GA₃ application in our experiment was suggested to be the result of increased SAM volume, which is mainly brought from the promotion of the cell division of the pith meristem and peripheral meristem in SAM.

**Acknowledgement**

We thank Dr. Nemoto for his valuable advice and Mr. Washizu, Mr. Ichikawa and Ms. Sasaki for their technical assistance in carrying out the experiment.

**References**


*In Japanese.
**In Japanese with English summary.
***In Japanese with English abstract.