Evaluation Method of Female Flower Bearing Ability in Watermelon using Silver Thiosulfate (STS)

Keita Sugiyama*, Tsuguo Kanno** and Masami Morishita
Kurume Branch, National Research Institute of Vegetables, Ornamental Plants and Tea, Kurume, Fukuoka 839-0851

Summary
Watermelon cultivars with high female flower bearing ability bore the first female flower at a lower node than those with low female flower bearing ability, when sprayed with silver thiosulfate, STS, at the cotyledonary stage or at the first true leaf stage. Also, watermelon seedlings sprayed with STS produced more female flowers than did the unsprayed control plants.
Correlation between the number of female flowers in the F2 population sprayed with 6 mM STS and the node order of the first female flowers is high. In a progeny selected from the F2 population, the female flower was borne at a lower node order of the main stem, whereas in another, the first female flower differentiated at a higher node order; the former had more female flowers than had the latter.
These results indicate that we are efficiently able to select the plants with high female flower bearing ability by STS treatment before transplanting.

Key Words: evaluation method, female flower, STS, selection, watermelon.

Introduction
Watermelon cultivars have fewer female flowers than other cucurbit crops such as cucumber and melon have. The formation of female flowers of watermelon is easily affected by temperature (Shibuya et al., 1967; Kurata, 1970, 1976; Rudich and Peles, 1976), day-length (Shibuya et al., 1967; Kurata, 1970, 1976; Rudich and Peles, 1976) and fertilizer conditions (Brantley and Warren, 1960).

A long pollination period is required in watermelon because the species differentiates few female flowers under high temperatures, long day-lengths, and when administered excess nitrogen. To improve fruit quality, advance maturity, and reduce cultivation labor, cultivars with a tendency to differentiate relatively more female flowers are desirable.

A testing method to evaluate a juvenile plants with many female flowers would be advantageous because much time is required to evaluate the female flower bearing ability of watermelon. There are many reports about the testing methods of gynoecious line breeding in cucumber (Fujieda, 1963; Fujita et al., 1981a, 1981b; Fujita, 1982), but a few about watermelons. Hence, we are tried to develop a simple method to evaluate the female flower bearing ability of watermelon before transplanting by using silver thiosulfate (STS).

Materials and Methods

Experiment 1. The effect of STS on induction of female flower breds
Seedlings of watermelon: ‘Red Seeded 3b’, ‘Kouryou 200’, ‘Beijing Xi C’, ‘Fujihikari TR’, ‘Aohanagawa’, ‘Summit’, ‘Klekley Sweet’ and ‘Green Seeded’ sown on Mar. 24, 1993, were sprayed with 0 (distilled water, control), 3, 6 and 12 mM STS at a) at the first true leaf stage on April 7, or b) the cotyledonary stage (seeds sown on Oct. 5) on Oct.14 with 0 (distilled water, control), 1, 3 and 6 mM STS. The quantity of solution sprayed was about 2 ml per plant. Ten plants per cultivar were used with two replications in all the treatments. The node order of the first female flower and the first male flower and the total number of female flowers up to the 10th or the 20th node on the main stem were recorded. Hermaphrodite flowers and degenerated female flowers were categorized as female.

Experiment 2. Selection effect of female flower bearing ability by STS treatment
F2 seedlings derived from the cross between ‘Red Seeded 3b’ with many female flowers and ‘Green Seeded’ with few female flowers. The F2 progenies

Received; October 21, 1996. Accepted; May 14, 1997.
* Present address: Japan International Research Center for Agricultural Sciences. 1-2 Owashi, Tsukuba, Ibaraki, 305-0851
** Present address: National Research Institute of Vegetables, Ornamental Plants and Tea, Taketoyo, Chita, Aichi 470-23
Part of this paper was presented at the 1993 Autumn Meeting of the Japanese Society for Breeding and the 1995 Spring Meeting of the Japanese Society for Horticultural Science.
(117) were sprayed with 6 mM STS at the cotyledonal stage on Apr. 5, 1994 (seeds sown on Mar. 24). From this population, two selections, RG94 and RG33 were selected; the former bore the first female flower at a basal node, whereas RG33 bore its first female flower at a more distal node. These selections were self-pollinated. Seeds of F₂ (79) and the seeds of F₃ population of RG94 (58) and RG33 (24) were sown Sept. 20. These plants were not treated with STS. The number of female flowers up to the 30th node on the main stem was recorded in F₂ and F₃ seedling population. Hermaphrodite flowers and degenerated female flowers were categorized as female as above.

**Results**

*Experiment 1a.*

At 3 mM and 6 mM STS, the first female flowers differentiated at a lower node order on the main stem compared with the control (Table 1, Fig. 1). The node orders bearing the first female flower in ‘Kouryou 200’, ‘Aohanagawa’ and ‘Green seeded’ were lowest in the 3 mM STS treatment, whereas those of ‘Red Seeded 3b’, ‘Beijing Xi C’, ‘Fujihikari TR’, ‘Summit’ and ‘Klekley Sweet’ were lowest in the 6 mM STS treatment. The cultivars with high female flower bearing ability had a tendency to form the first female flower on the lower nodes of the main stem. When ‘Red Seeded 3b’ and ‘Kouryou 200’ treated with 6 mM STS, initiated their first female flowers at node 4, whereas ‘Klekley Sweet’ and ‘Green seeded’ bore them on node 8 and 13, respectively. At the same STS concentration, ‘Summit’ and ‘Aohanagawa’ bore their first female flowers on node 6 and 7, respectively.

In ‘Beijing Xi C’, ‘Aohanagawa’ and ‘Klekley Sweet’ sprayed with 12 mM, the node order bearing the first female flower was lower than in the control, whereas with ‘Kouryou 200’, ‘Fujihikari TR’ and ‘Summit’ it was higher. Seedlings of ‘Beijing Xi C’ and ‘Aohanagawa’ treated with 12 mM STS differentiated more female flowers than did the control, whereas other cultivars initiated equal numbers of female flowers. Thus, the effect of the 12 mM STS treatment on induction of female flower was variable, partly because the treatment was phytotoxic.

When seedlings were treated with 6 mM STS at the first true leaf stage, the node bearing the first female flower was lowered in most cultivars.

The effect of STS treatment on induction of male flower was not clear.

*Experiment 1b.*

Spraying STS at the cotyledonal stage was more

![Fig. 1. Effect of STS on the first female flower setting. Right is the plantlet which first female flower was induced at the 3rd nodes on the main stem by STS treatment. Left is control (distilled water).](image)

### Table 1. The effect of STS treatment at the first true leaf stage on sex expression in watermelon.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>The node order bearing the first female flower</th>
<th>Number of female flowers up to 10 th node</th>
<th>The node order bearing the first male lower</th>
<th>No. of female flowers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 mM²</td>
<td>3 mM</td>
<td>6 mM</td>
<td>12 mM</td>
</tr>
<tr>
<td>Red Seeded 3b</td>
<td>5.3 a</td>
<td>4.9 ab</td>
<td>4.0 a</td>
<td>–</td>
</tr>
<tr>
<td>Kouryou 200</td>
<td>5.3 a</td>
<td>4.8 a</td>
<td>4.0 a</td>
<td>6.7</td>
</tr>
<tr>
<td>Beijing Xi C</td>
<td>6.3 a</td>
<td>5.4 ab</td>
<td>4.9 ab</td>
<td>6.2</td>
</tr>
<tr>
<td>Fujihikari TR</td>
<td>6.7 a</td>
<td>5.3 bc</td>
<td>5.7 bc</td>
<td>7.4</td>
</tr>
<tr>
<td>Aohanagawa</td>
<td>8.8 a</td>
<td>6.4 bc</td>
<td>7.0 c</td>
<td>7.0</td>
</tr>
<tr>
<td>Summit</td>
<td>9.1 b</td>
<td>7.3 c</td>
<td>6.2 c</td>
<td>9.6</td>
</tr>
<tr>
<td>Klekley Sweet</td>
<td>10.5 b</td>
<td>10.3 d</td>
<td>8.4 d</td>
<td>10.0</td>
</tr>
<tr>
<td>Green Seeded</td>
<td>14.8 c</td>
<td>10.8 d</td>
<td>13.4 e</td>
<td>–</td>
</tr>
</tbody>
</table>

Sowing date was Mar. 24, 1993. STS treatment was made on Apr. 7, 1993.

* On the main stem, including hermaphrodite.

²S On STS concentration.

³ Mean separation within columns by Duncan's multiple range test, at 5 % level.

⁴ Correlation coefficient between node order of the first female flower and total number of female flowers up to 20 th node in control.

⁵ Significant at the 1 % level.
effective on inducing female flowers at a lower node than that administered at the first true leaf stage in almost all cultivars (Table 2). Treatment with 6 mM STS lowered the node order of the first female flower on the main stem in cultivars with many female flowers by two node compared to that in the control. In ‘Red Seeded 3b’ treated with 6 mM STS, which had the highest frequency of female flowers, the mean node for the first female flower was 3.4, whereas in ‘Kouryou 200’ and ‘Beijing Xi C’, which are cultivars with many female flowers, the mean nodes were 3.8 and 4.4, respectively. With the same treatment, the basal nodes with the first female flowers of ‘Aohanagawa’ and ‘Klekley Sweet’ were 7 and 8, respectively, which is significantly lower than that in the control. Yet, the node order was still higher than all other cultivars except for ‘Green Seeded’. The node order of the first female flower of ‘Green Seeded’ was lowered by the 1 mM STS treatment, but the 3 or 6 mM STS was ineffective.

Spraying 1 mM STS was slightly effective in lowering the node order of the first female flower. Differences in female flower bearing ability among cultivars were clearly shown when seedlings were sprayed with 6 mM STS.

Seedlings sprayed with 3 or 6 mM STS was effective in increasing of the number of female flowers; concurrently, the node order bearing the first male flower tended to be raised by STS treatment.

Correlation coefficient between the node order of the first female flower in STS treated plants and the number of female flowers up to 20th node in nontreated plants is very high.

**Experiment 2.**

A wide range of node order bearing the first female flower was observed in the F2 population of the watermelon cultivars tested. The lowest node order bearing the first female flower was 3, while the highest node order bearing the first female flower was 14 (Fig. 2). The watermelon plants bearing many female flowers had a tendency to bear the first female flower at a lower node. Contrarily, the watermelon cultivars bearing fewer female flowers tended to bear them at a higher node. Correlation coefficient between the number of female flowers up to the 30th node on the main stem and the node order bearing the first female flower was significantly high.

Two plants were selected from the F2 population; one was RG94 for which the first female flower bearing node order was 4; the other one was RG33 which bore the first female flower on the 10th node.

F3 plants derived from RG94 bear more female flowers than those from RG33 and F2 plants (Fig. 3).

**Discussion**

It is known that the female flowers (including hermaphrodite flowers) of watermelon are increased by aminooxyxynlglucine (Christopher and Loy, 1982), silver nitrate (Christopher and Loy, 1982; Kurata and Torichigai, 1983) and maleic hydrazide (Yagi, 1975) applications. Triiodobenzoic acid treatment increased the production of female flowers and induced the formation of the first female flower at lower nodes of the main stem (Gopalkrishnan and Choudhury, 1969). On the other hand, ethephon treatment decreased the number of female flowers (Christopher and Loy, 1982). It was supposed that there were some methods for selecting female flower bearing ability. One method was to select plants which differentiated female flowers under conditions inhibitory to female flower formation such as long day-length, high temperature, or with treatments with certain plant growth regulator such as ethephon or conversely to select plants which initiate female flowers under favorable conditions, such as short

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**Table 2.** The effect of STS treatment at the cotyledonary stage on sex expression in watermelon.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>The node order bearing the first female flower</th>
<th>Number of female flowers up to 10th node</th>
<th>The node order bearing the first male flower</th>
<th>No. of female flowers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 mM* 1 mM 3 mM 6 mM</td>
<td>0 mM* 1 mM 3 mM 6 mM</td>
<td>0 mM* 1 mM 3 mM 6 mM</td>
<td></td>
</tr>
<tr>
<td>Red Seeded 3b</td>
<td>5.4 a 4.0 a 5.6 a 3.4 a</td>
<td>2.5 a 2.6 a 3.6 a 3.2 a</td>
<td>3.1 a 3.6 a 5.5 a 5.1 a</td>
<td>4.8 a</td>
</tr>
<tr>
<td>Koryou 200</td>
<td>6.1 a 5.6 ab 4.9 ab 3.8 ab</td>
<td>2.0 a 1.7 b 2.3 b 3.0 b</td>
<td>4.4 b 5.1 c 5.0 ab 5.0 ab</td>
<td>3.7 b</td>
</tr>
<tr>
<td>Beijing Xi C</td>
<td>6.6 a 5.4 ab 4.9 ab 4.4 ab</td>
<td>1.5 bc 1.9 b 2.2 b 2.3 cd</td>
<td>4.9 b 4.6 b 5.6 bc 5.6 bc</td>
<td>3.6 bc</td>
</tr>
<tr>
<td>Fujishikari TR</td>
<td>7.7 a 6.5 b 6.1 bc 5.6 bc</td>
<td>1.2 c 1.2 c 1.9 c 1.9 d</td>
<td>4.4 b 4.2 ab 4.4 a 4.4 a</td>
<td>3.1 c</td>
</tr>
<tr>
<td>Aohanagawa</td>
<td>11.7 b 7.7 b 7.0 cd 7.2 cd</td>
<td>0.4 d 0.6 c 1.4 cd 1.1 ef</td>
<td>6.8 d 7.3 d 6.8 de 6.2 c</td>
<td>1.4 de</td>
</tr>
<tr>
<td>Klekley Sweet</td>
<td>13.4 bc 14.0 c 8.5 d 8.0 d</td>
<td>0.3 d 0.3 d 0.9 d 0.8 fg</td>
<td>5.7 c 6.9 d 6.8 de 6.2 c</td>
<td>1.4 de</td>
</tr>
<tr>
<td>Green Seeded</td>
<td>15.0 c 15.3 c 15.4 e 15.5 e</td>
<td>0.1 d 0.3 d 0.3 e 0.3 g</td>
<td>5.0 b 6.0 c 5.6 cd 5.7 bc</td>
<td>0.8 e</td>
</tr>
</tbody>
</table>

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**Sowing date was Oct. 5, 1993. STS treatment was made on Oct. 14, 1993.**

* On the main stem, including hermaphrodite.

* STS concentration.

* Up to 20th node on the main stem in control.

* Mean separation within columns by Duncan’s multiple range test, at 5% level.

* Correlation coefficient between node order of the first female flower and total number of female flowers up to 20th node in control.

** Significant at the 1% level.
day-length, low temperature or some of the above-mentioned substances.

Sugiyama et al. (1993) exposed watermelon seedlings to high temperature and long photoperiod to select the plants with many female flowers but the method requires a large, expensive phytotron for a long duration.

We applied STS which is more easily absorbed by the plant than silver nitrate. STS applied at the cotyledonary stage or first true leaf stage to induce the first female flower at a lower node on the main stem and to increase the number of female flowers. It was supposed that the cultivars with many female flowers had a tendency to bear the first female flower at the lower node under STS treatment.

By selecting two progenies from a F₂ population bearing female flowers at a lower or upper nodes on the main stem, we demonstrated that this bearing habit is heritable. Hence, we are able to select the plants with high female flower bearing ability by STS treatments. This testing method should enable us to select the plants with many female flowers before transplanting, thereby improve efficiency by shortening the turnover generation in watermelon breeding.
多雌花性スイカを苗期に選抜するために、STS（チオ硫酸銀）を利用した簡易な選抜法を検討した。
1）子葉展開期、萼葉1枚展開期に3～6mMのSTSを葉面散布（2ml/株）することにより、第1雌花着生節位が無処理区よりも低下した。子葉展開期の被着処理により、第1雌花着生節位が高く、無処理区に比べて平均約2節低下し、その結果第1雌花着生節位の低い系統では4節位から雌花が着生した。雌花着生数の多種品種ほどSTS処理によって第1雌花着生節位が下がる傾向が認められた。
2）雌花着生数の多い品種と少ない品種のF2集団においても、STS処理後の第1雌花着生節位と低い個体ほど雌花着数の多い傾向が認められた。STS処理されたF2集団から第1雌花着生節位の低い個体と高い個体を選抜して、それらのF3世代における雌花着生数を観察したところ、第1雌花着生節位の低い個体の後代も雌花着生数が多くなり、第1雌花着生節位による選抜効果が認められた。以上の結果から、子葉期にSTS処理することによって、定植適期（本葉5～6枚）までに多雌花性個体を選抜することが可能であった。また、本手法により、従来定植後に判断されていた多雌花性個体の選抜が苗期段階で可能となり、育種効率の向上に大きく寄与すると考えられた。

**文献**