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Varietal Differences in Female Flower Bearing Ability and Evaluation Method in Watermelon

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Abstract

These studies were carried out to identify varieties with a high female flower bearing ability among genetic resources and develop a simple method to evaluate the female flower bearing ability of watermelon before transplanting. The results showed that Japanese F_1 varieties bore more female flowers than the other varieties except for those from China and Taiwan. Also varieties with many female flowers among wild species could be used as breeding materials to improve the female bearing ability of other watermelon varieties. Watermelon varieties with a high female flower bearing ability bore the first female flower at a lower node than those with a low female flower bearing ability, when sprayed with silver thiosulfate, STS, at the cotyledonary stage. Correlation between the number of female flowers in the F_2 population sprayed with 6 mM STS and the node order of the first female flowers was high. In a progeny selected from the F_2 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 bore more female flowers than the latter. These results indicate that it is possible to select plants with a high female flower bearing ability by STS treatment before transplanting.

Discipline: Plant breeding
Additional key words: *Citrullus lanatus*, STS, selection

Introduction

Watermelon varieties have fewer female flowers than other cucurbit crops such as cucumber and melon. The formation of female flowers in watermelon is easily affected by the temperature[8,9,11,12], day-length[8,9,11,12] and fertilizer conditions[1].

A long pollination period is required in watermelon because the species differentiates few female flowers under high temperature and long day-length conditions and when excess nitrogen is applied. Furthermore, abortion of female flowers or low fruit-setting ratio is caused by weather conditions characterized by a low temperature and little sunshine. Also, to set the fruit at the nodes which are convenient for improving fruit quality and reducing cultivation labor, varieties with a tendency to differentiate relatively more female flowers should be used.

A testing method to evaluate juvenile plants with a high female flower bearing ability would be advantageous because much time is required to evaluate the female flower bearing ability of watermelon. There are many reports in testing methods for gynoecious line breeding in cucumber[3–6], but only a few in watermelons. Hence, we attempted 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: Varietal differences in female flower bearing ability in watermelon

Forty-five Japanese watermelon varieties (19 purebred varieties, 12 F_1 small-sized watermelon varieties and 14 F_1 large-sized watermelon varieties), 10 watermelon varieties derived from China and Taiwan, 12 watermelon varieties derived from America, Russia, Europe and other countries and 9 wild watermelon varieties were used in this experiment (Table 1). They were sown on March 21 and transplanted to a greenhouse on April 15, 1994. Four plants per variety were used with 2 replications. The total number of female flowers up to the 30th node on the main stem was recorded. Hermaphrodite flowers and

Table 1. List of watermelon varieties

Japanese varieties	Foreign varieties	
Pure-bred varieties	Wild species	
Akashi 3	Red Seeded 3b	AFRICA[a)]
Asahiyamato	Africa 22857	AFRICA
Fumin	Ind 22858	INDIA
Ginyamato	Wild 22859	AFRICA
Kurobe	Wild bitter Tsmma	RUSSIA
Mikasa	WIR-4801-3	RUSSIA
Miyako 1	Africa 22860	AFRICA
Miyako 3	Citron Green Seeded	AFRICA
Nishikiyamato		
Oukan	America, Russia and other countries	
Shinyamato 3	Demintus	?
Tabata	Dr. Much	?
Tabatakanro	FR-71	USA
Yamatokuriimu 2	Fair fax	USA
Benikodama	Ginza No. 1	EGYPT
Otome	Gzauudela	RUSSIA?
Ounikukodama	Klondike blue ribbon striped	USA
Tomoe	Klekley Sweet	USA
Kuriimu	Metitopeal skij	RUSSIA
F_1 varieties (Large-sized watermelon)	Summit	USA
Fujihikari TR	Skolospelka	RUSSIA?
Wasenisshou	Torkmen Skijmramorgj	RUSSIA
Zuisho	Tom Watson	URUGUAY
Koryou 200	Calhoun Gray	ITALY
Koudai	Crimson Sweet	USA
Kansen	Sugar baby	USA
Shimao Max KE	WM-92001	BANGLADESH
Parnassus queen		
Kyoho L	China and Taiwan	
Kunzan	Qing hoa pi	
Tenryu 2	Beijing Xi C	
Daimonji	Jia bao	
Honey charmant	Lu quan	
Lemony	Zheng za 5 hou	
F_1 varieties (Small-sized watermelon)	S-7	
Madder bowl	Yi xuan	
Kinsuzu	Hu mi 3 hou	
Otori 2	Zao jiang	
Kogane kodama	Zhu lan	
Kodama baby		
Maiko		
Rabbit		
Midget		
Coney		
Repo		
New kodama		
Benitubasa		

a): Name of country or region of introduction.

degenerated female flowers were categorized as female.

Experiment 2: Effect of STS on the induction of female flowers

Seedlings of watermelon, 'Red Seeded 3b', 'Koryou 200', 'Beijing Xi C', 'Fujihikari TR', 'Aohanagawa', 'Summit', 'Klekley Sweet' and 'Green Seeded' sown on March 24, 1993, were sprayed with 0 (distilled water, control), 1, 3 and 6 mM STS at the cotyledonary stage (seeds sown on October 5) on October 14. The amount of solution sprayed was about 2 mL per plant. Ten plants per variety were used with 2 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 3: Selection effect of female flower bearing ability by STS treatment

F_2 seedlings were derived from the cross between Red Seeded 3b with many female flowers and Green Seeded with a few female flowers. The F_2 progenies (117) were sprayed with 6 mM STS at the cotyledonary stage on April 5, 1994 (seeds sown on March 24). From this population, 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 the F_2 population (79) and seeds of the F_3 population of RG94 (58) and RG33 (24) were sown on September 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 the F_2 and F_3 seedling populations. Hermaphrodite flowers and degenerated female flowers were categorized as female as above.

Results

Experiment 1: Varietal differences in female flower bearing ability in watermelon

Average number of female flowers up to the 30th node on the main stem was 3.7 flowers (Fig. 1). Red Seeded 3b bore the largest number of female flowers (7.1 female flowers) followed by Africa 22860 with 6.1 female flowers. It was found that Green Seeded bore the lowest number with 0.5 female flowers. Thus, wild species displayed a wide range of female flower bearing ability.

The varieties from America, Russia, Europe and other countries bore fewer female flowers than the Japanese varieties. However, the varieties of China and Taiwan showed almost the same number of female flowers as the Japanese F_1 varieties.

Japanese pure-bred varieties were found to display a wide range of female flower bearing ability. However, small-sized and large-sized watermelons and Japanese F_1 varieties bore about 3 to 4.5 and 4 to 5 female flowers, respectively. Thus, large-sized watermelon and Japanese F_1 varieties were found to bear the largest number of female flowers.

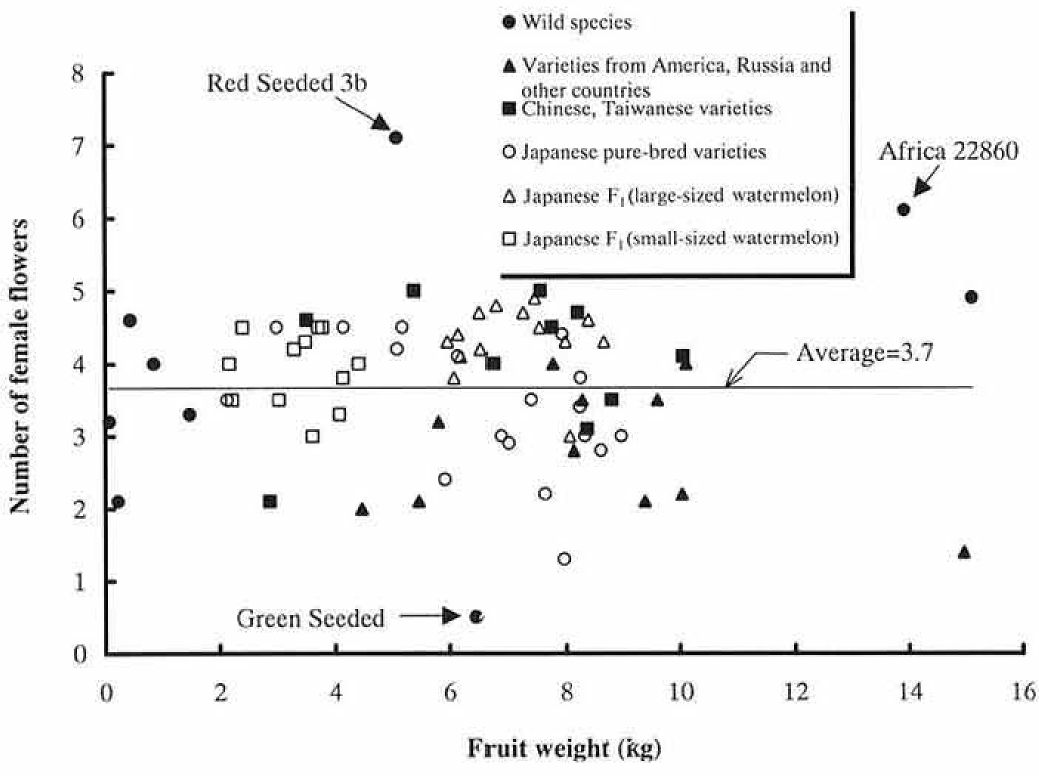

Fig. 1. Varietal differences in number of female flowers in genetic resources

Experiment 2: Effect of STS on the induction of female flowers

Spraying STS at the cotyledonary stage was effective in inducing female flowers (Table 2, Fig. 2). Treatment with 6 mM STS lowered the node order of the first female flower on the main stem in varieties with many female flowers by 2 nodes compared to that in the control. In Red Seeded 3b treated with 6 mM STS, which showed the highest frequency of female flowers, the mean node order for the first female flower was 3.4, whereas in Koryou 200 and Beijing Xi C, which bear many female flowers, the mean node order was 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, a value significantly lower than that in the control. Yet, the node order was still higher than for all the other varieties except for Green Seeded. The node order of the first female flower of Green Seeded was lowered by the 1 mM STS treatment, while the application of 3 or 6 mM STS was ineffective.

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

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

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

Experiment 3: Selection effect of female flower bearing ability by STS treatment

A wide range of node orders bearing the first female flower was observed in the F_2 population of the watermelon varieties 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. 3). The watermelon plants bearing many female flowers tended to bear the first female flower at a lower node. In contrast, the watermelon varieties 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.

Table 2. Effect of STS treatment at the cotyledonary stage on sex expression in watermelon

Variety	Node order bearing the first female flower[a]				Number of female flowers up to 10th node[a]				Node order bearing the first male flower				Number of female flowers[c]
	0 mM[b]	1 mM	3 mM	6 mM	0 mM	1 mM	3 mM	6 mM	0 mM	1 mM	3 mM	6 mM	
Red Seeded 3b	5.4a[d]	4.0a	3.6a	3.4a	2.5a	2.9a	3.6a	3.8a	3.1a	3.6a	5.5bc	5.1ab	4.8a
Koryou 200	6.1a	5.6ab	4.9ab	3.8ab	2.0b	1.7b	2.3b	3.0b	4.4b	5.1c	5.0ab	5.0ab	3.7b
Beijing Xi C	6.6a	5.4ab	4.9ab	4.4ab	1.5bc	1.9b	2.2b	2.3cd	4.9b	4.6b	5.6bc	5.6bc	3.6bc
Fujihikari TR	7.7a	6.5b	6.1bc	5.6bc	1.2c	1.2c	1.6c	1.9d	4.4b	4.2ab	4.4a	4.4a	3.1c
Aohanagawa	11.7b	7.7b	7.0cd	7.2cd	0.4d	0.6c	1.4cd	1.1ef	6.8d	7.3d	7.2e	6.6c	1.5d
Klekley Sweet	13.4bc	14.0c	8.5d	8.0d	0.3d	0.0d	0.9d	0.8fg	5.7c	6.9d	6.8de	6.2c	1.4de
Green Seeded	15.0c	13.3c	15.4e	15.8e	0.1d	0.3d	0.3e	0.3g	5.0b	6.0c	5.6cd	5.7bc	0.8e
r[e]	-0.97**	-0.89**	-0.84**	-0.84**									

Sowing date: Oct. 5, 1993. STS treatment was applied on Oct. 14, 1993.
a): On the main stem, including hermaphrodite.
b): STS concentration.
c): Up to 20th node on the main stem in control.
d): Mean separation within columns by Duncan's multiple range test, at 5% level.
e): Correlation coefficient between node order of the first female flower and total number of female flowers up to 20th node in control.
** Significant at 1% level.

Fig. 2. Effect of STS on first female flower setting
Right: Plantlet in which 1st female flower was induced at the 3rd node on the main stem by STS treatment.
Left: Control plant sprayed with distilled water, with 5 nodes but no female flowers.

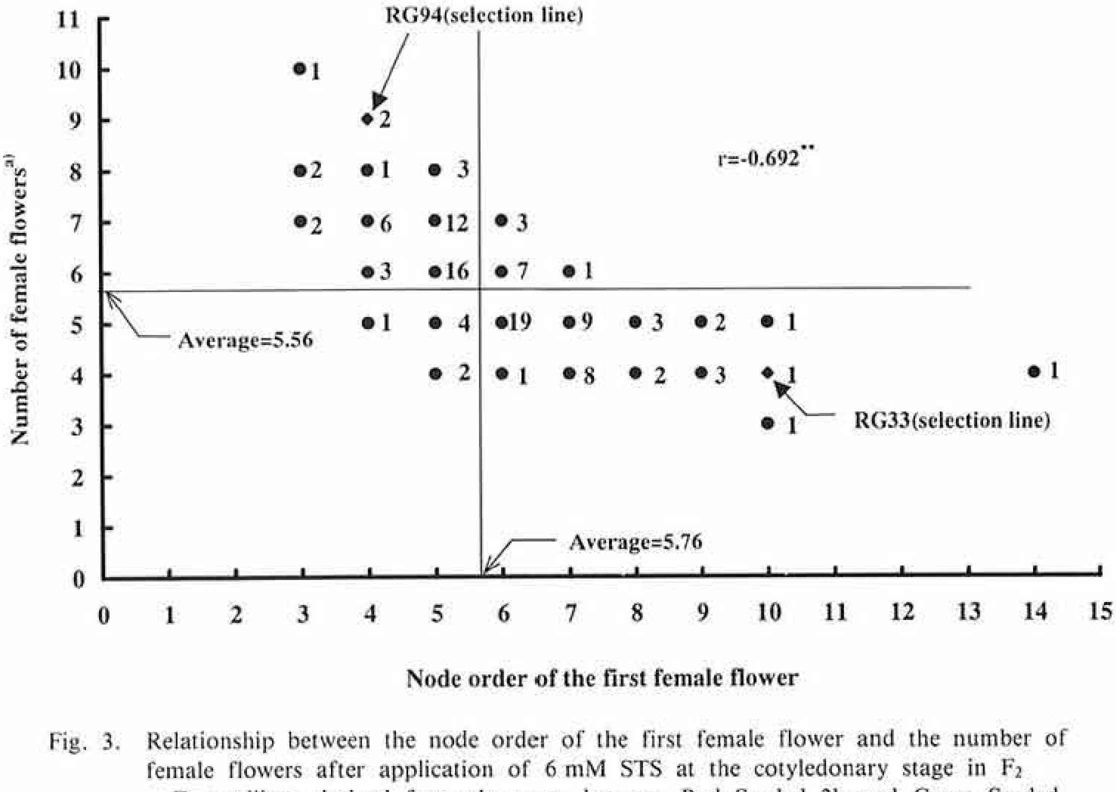

Fig. 3. Relationship between the node order of the first female flower and the number of female flowers after application of 6 mM STS at the cotyledonary stage in F_2
F_2 seedlings derived from the cross between Red Seeded 3b and Green Seeded.
Sowing date: March 24, 1994. STS treatment date: April 5, 1994.
a): Up to the 30th node on the main stem.
** Significant at 1% level.
Arabic numerals: Number of plants. 117 plants were used.

Two plants were selected from the F_2 population: one was RG94 for which the first female flower bearing node order was 4 and the other one was RG33 which bore the first female flower on the 10th node.

The F_3 plants derived from RG94 bore more female flowers than those derived from RG33 and F_2 plants (Fig. 4).

Discussion

Female flower bearing ability in the Japanese F_1 varieties is higher than that of Japanese pure-bred varieties or varieties from other countries except for China and Taiwan. It is assumed that recently Japanese F_1 varieties have been improved to become adapted to greenhouse culture. The varieties were altered with a high bearing ability to stabilize the setting of fruits as well as to advance maturity and reduce the cultivation labor. However, the Japanese F_1 varieties did not bear many female flowers. This problem may have been solved by the application of a training method which enabled to increase the number of female flowers by growing 3 or 4 lateral vines of watermelon plant. However, since the female flower bearing is easily affected by the weather conditions, it is necessary to genetically alter varieties to increase their female flower bearing ability. Red Seeded 3b and Africa 22860 with a high female flower bearing ability are suitable for use as breeding materials.

It is generally recognized that the number of female flowers (including hermaphrodite flowers) of watermelon can be increased by aminoethoxyvinylglycine[2)], silver nitrate[2,10)] and maleic hydrazide[14)] 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[7)]. On the other hand, ethephon treatment decreased the number of female flowers[2)]. It was assumed that the use of some methods may enable to carry out selection for female flower bearing ability. In one method, selection involved 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 regulators such as ethephon or conversely, the selection involved plants which initiate female flowers under favorable conditions, such as short day-length, low temperature or with some of the above-mentioned substances.

Sugiyama et al.[13)] exposed watermelon seedlings to high temperature and long photoperiod to select plants with a high female flower bearing ability but the method requires a large and expensive phytotron for a long duration.

We applied STS which is more easily absorbed by the plant than silver nitrate. STS was applied at the cotyledonary 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 assumed that the varieties with many female flowers

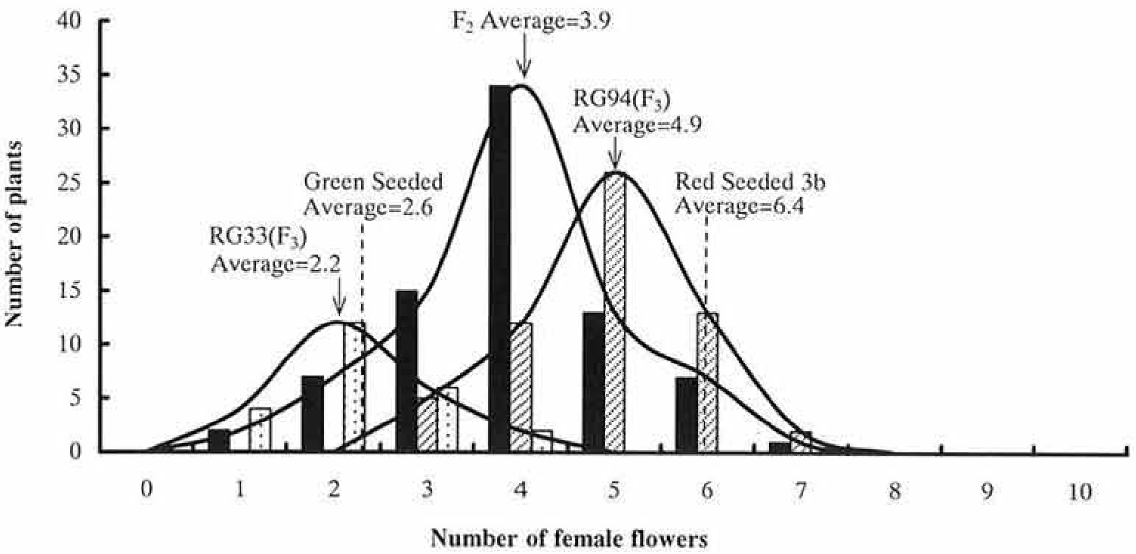

Fig. 4. Frequency distribution of number of female flowers of F_2, RG33(F_3) and RG94(F_3)
Sowing date: Sept. 20, 1994.
The number of female flowers was counted up to the 30th node on the main stem.

tended to bear the first female flower at a lower node under STS treatment.

By selecting 2 progenies from an F_2 population bearing female flowers at lower or upper nodes on the main stem, we demonstrated that this bearing habit is heritable. Hence, we were able to select plants with a high female flower bearing ability by STS treatments. This testing method should enable to select plants with a high female flower bearing ability before transplanting, in order to improve the efficiency by shortening the turnover generation in watermelon breeding.

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