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Control of Sex Expression in Cucumber by Photoperiod, Defoliation, and Plant Growth Regulators

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ABSTRACT.

Influences of photoperiod, defoliation, and growth regulators ($AgNO_3$, ethephon, gibberellic acid, and uniconazole) on sex expression were observed in three cultivars of cucumber, *Cucumis sativus* L. Eight photoperiod (SD) condition increased number of pistillate flowers and decreased number of staminate flowers in a monoecious cucumber, 'Sagami-hanjiro'. Defoliation increased number of staminate flowers under SD. Ethephon decreased number of staminate flowers under SD, but had no effect under 24 h light photoperiod (LD) in defoliated plants. Gibberellic acid (GA_3) increased number of staminate flowers regardless of photoperiod and defoliation. LD slightly increased number of staminate flowers in a monoecious 'Otone No. l'. Defoliation significantly decreased number of pistillate flowers under LD. Ethephon decreased number of staminate flowers and increased pistillate flowers under both photoperiodic conditions. The effect of ethephon was nullified by defoliation. Uniconazole markedly decreased number of staminate flowers and increased pistillate flowers regardless of photoperiod and defoliation. Uniconazole also induced bisexual flowers. A gynoecious cucumber, 'Rensei' produced almost only pistillate flowers under both SD and LD, and this tendency was not affected by defoliation. $AgNO_3$ induced staminate flowers and decreased number of pistillate flowers under LD and also under SD if defoliated. GA_3 decreased number of pistillate flowers in all treatments by causing blind nodes where neither floral nor vegetative buds developed.

Key words cucumber, sex expression, photoperiod, defoliation, ethephon, gibberellin, uniconazole

INTRODUCTION

The sex expression of cucumber (*Cucumis sativus* L.) depends on genetic basis, environmental factors, nutrition, defoliation and phytohormones (Malepszy and Niemirowicz-Szczytt, 1991; Saito *et al*, 1988). Among phytohormones, gibberellin and ethylene play important roles. Gibberellin (Clark and Kenney, 1969), ethylene synthesis inhibitor and ethylene antagonist (Atsmon and Tabbak, 1979) increased the number of staminate flowers. On the other hand, ethylene (Augustine *et al.*, 1973), gibberellin synthesis inhibitor and gibberellin antagonist (Rodriquez and Lambeth, 1972) increased the number of pistillate flowers in monoecious cucumber. However, transformation of flower sex from staminate to bisexual and then to pistillate flower in cucumber also relates to some substance (s) produced in leaves (Saito *et al.*, 1988). Only a few studies have described interaction of these effects. Different cultivars may respond to photoperiod and growth regulators in different way. Effects of photoperiod, plant growth regulators, and defoliation on sex expression were investigated in several combinations in cucumber with different genetic backgrounds.

MATERIALS AND METHODS

Two cultivars of monoecious cucumber, *Cucumis sativus* L., 'Sagami - hanjiro' and 'Otone No. l' and one gynoecious cultivar, 'Rensei' were used. Generally, 'Sagami- hanjiro' produces staminate flowers at lower nodes and pistillate flowers at higher nodes. Main stem of 'Otone No.l' mainly produces staminate flowers, occasionally produces pistillate flowers. 'Rensei' produces only pistillate flowers. The seeds were soaked in water and left overnight in darkness at 30 C. The germinated seeds were planted in 10 cm diameter plastic pots containing soil with 15-15-15 fertilizers. The plants

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were grown under continuous light; natural daylight with additional light by 100 watt incandescent lamps (Toshiba) providing about 32 μmol.m^{-2}.s^{-2} at the plant level. Watering and fertilization were done according to ordinary cultural practices. The plants were grown from May to July in a greenhouse in the Faculty of Agriculture, Tohoku University, Japan. When the plants reached expanding cotyledon stage, this experiment was started. The experiment used factorial in completyly randomise design with three factors (photoperiods, defoliation and plant growth regulators). The plants were subjected to long day (LD) and short day (SD) treatments. For the LD treatment, plants were grown in a glasshouse under natural daylight from 8:30 am. to 4:30 pm. and irradiated with incandescent lights as mentioned above. For the SD treatment, the plants were grown under natural daylight from 8:30 am. to 4:30 pm., then the plants were transferred into a darkroom. The photoperiodic treatment was repeated for 30 days, afterwards the plants were grown under continuous light. In defoliation treatment, the foliage leaves were removed when they reached 2.5 cm in length until the 5th leaf stage. The plants were sprayed 3 times at 10 day intervals with growth regulators. 'Sagami-hanjiro' was sprayed with 100 ppm ethephon (10% of 2-chloroethyl-sulphonic acid, 90% solution solvent, Nissan chemicals Co., Ltd.). or 30 ppm gibberellic acid (GA_3, Tokyo Kasei Industrial Co., Ltd.). 'Otone No.1' was sprayed with 100 ppm ethephon or 5 ppm uniconazole (Sumitomo Chemical Co., Ltd.). 'Rensei' was sprayed with 100 ppm silver nitrate ($AgNO_3$, Junsei chemical Co., Ltd.) or 500 ppm GA_3.

Sex of all the flowers on the main shoots until the twentieth node was observed.

RESULTS

1. The node positions of the first flower, first staminate and first pistillate flowers.

The first flowers of 'Sagami-hanjiro' were found at the second node under SD while they were formed at the third node under LD (Table I). The first flowers were staminate flower under both photoperiodic conditions. Defoliation raised the node position of the first flower and first pistillate flower under both photoperiods.

The first flowers were formed at the second node under SD and at the third node under LD in 'Otone No. I' (Table I). The first flowers were staminate flowers under both photoperiodic conditions. Defoliation raised the node position of the first flower under SD, but had no effect under LD. The defoliation exhibited a little effect on raising the node of the first pistillate flower under SD, but had a strong effect under LD.

The first flowers of 'Rensei' were formed at the second node, and were pistillate under both photoperiodic conditions (Table I). Defoliation raised the node position of the first flower under both conditions. The staminate flowers were formed only under LD. The defoliation had a little effect on lowering the node position of the first staminate flower.

Table I Effect of photoperiod and defoliation on position of nodes at which the first flower, first staminate and pistillate flowers were formed in three cucumber cultivars.[Z]

Cultivar	Photo-period	Defoliation[Y]	Node of Ist flower	Node of Ist staminate flower	Node of Ist pistillate flower
	SD	-	2.0 ± 0.00	2.0 ± 0.00	8.4 ± 0.95
Sagami-Hanjiro	SD	+	2.9 ± 0.17	2.9 ± 0.17	18.0 ± 0.40
	LD	-	3.2 ± 0.24	3.2 ± 0.24	15.4 ± 0.67
	LD	+	4.6 ± 0.32	4.6 ± 0.32	18.5 ± 0.41
	SD	-	1.9 ± 0.09	1.9 ± 0.09	5.1 ± 0.0
Otone-NO. 1	SD	+	2.6 ± 0.23	2.6 ± 0.32	7.1 ± 0.70
	LD	-	2.7 ± 0.31	2.7 ± 0.31	6.1 ± 0.57
	LD	+	2.3 ± 0.15	2.3 ± 0.15	13.9 ± 0.67
	SD	-	2.3 ± 0.14	——	2.3 ± 0.14
Rensei	SD	+	3.0 ± 0.00	——	3.0 ± 0.00
	LD	-	2.6 ± 0.38	12.0 ± 0.71	2.6 ± 0.38
	LD	+	3.2 ± 0.28	8.5 ± 1.77	3.2 ± 0.28

Z Each value is mean of ten replication ± SE.
Y - = Nondefoliation , + = Defoliation.

2. Number of flowers of each sex in monoecious cucumber 'Sagami-hanjiro'.

The plant grown under LD condition produced greater number of staminate flowers than the plants grown under SD condition (Table 2). The defoliation increased the number of staminate flowers under SD, but only slightly under LD. The largest number of pistillate flowers was observed under combined treatment of SD and nondefoliation.

Ethephon decreased nuber of staminate flowers under SD. However, ethephon did not decrease the number of staminate flowers under LD, and also under SD if the plants were defoliated. Ethephon increased number of pistillate flowers in defoliated plants under SD and in intact plants under LD.

The application of GA_3 influenced sex expression only in the intact plant under SD. It increased the number of staminate flowers and decreased number of pistillate flowers.

3. Number of flowers of each sex in monoecious cucumber 'Otone No. 1'.

The plant produced greater number of the staminate flowers and smaller number of pistillate flowers under LD than under SD (Table 3). Defoliation had no effect on number of staminate flowers in both SD and LD conditions. Defoliation decreased the number of pistillate flowers under LD condition but did not occur under SD.

Ethephon decreased the number of staminate flowers under both photoperiods, but did not decrease in defoliated plants regardless of photoperiod. Ethephon increased the number of pistillate flowers under both SD and LD. Defoliation nullified this effect of ethephon.

Uniconazole had strong effect on decreasing the number of staminate flowers and increasing number of pistillate flowers in all the conditions. Furthermore, Uniconazole induced bisexual flowers.

4. Numbers of flowers of each sex in gynoecious cucumber 'Rensei'.

The photoperiod and defoliation had no effects on number of staminate and pistillate flowers (Table 4).

$AgNO_3$ induced the staminate flowers under both SD and LD conditions. $AgNO_3$ decreased number of pistillate flowers in all experimental lots except intact plants under SD.

GA_3 had no effect on the number of staminate flowers. However, GA_3 decreased number of pistillate flowers. GA_3 caused 'blind' nodes where neither floral nor vegetative buds developed.

DISCUSSION

There had been many reports on effect of photoperiod on the sex expression in cucumbers. The pistillate tendency is increased under short photoperiod in monoecious cucumbers (Atsmon and Galun, 1962) and in an androecious cucumber (Rudich *et al.*, 1976). On the other hand, the optimum for staminate flower production in gherkin was 8 hr photoperiod (Danielson,

Table 2 Effects of photoperiod, defoliation and growth regulators on number of nodes with staminate and pistillate flowers in 'Sagami-hanjiro' cucumber.[Z]

Photo-period	Defoliation[Y]	Growth regulator	Number of nodes with staminate flower	Number of nodes with pistillate flowr
SD	-	Control	8.2 e[X]	11.4 a
SD	-	Ethephon	5.9 f	12.3 a
SD	-	GA_3	11.5 d	8.0 b
SD	+	Control	16.8 ab	1.2 d
SD	+	Ethephon	15.2 bc	3.1 c
SD	+	GA_3	17.4 a	0.3 d
LD	-	Control	15.6 abc	1.1 d
LD	-	Ethephon	11.2 d	7.3 b
LD	-	GA_3	15.5 abc	1.4 d
LD	+	Control	16.1 ab	1.2 d
LD	+	Ethephon	14.9 c	1.4 d
LD	+	GA_3	17.1 ab	0.5 d

Z Data corrected from the lst node to the 20th node of main shoot.
Y - = Nondefoliation, + = Defoliation.
X Means within columns with different letter are significanty at the 0.05 probability level.

Table 3. Effects of photoperiod, defoliation and growth regulators on number of nodes with staminate, pistillate and bisexual flowers in 'Otone No I' cucumber.[Z]

Photo-period	Defoliation[Y]	Growth regulator	Number of nodes with staminate flower	Number of nodes with pistillate flower	Number of nodes with bisexual flower
SD	-	Control	12.4 b[X]	7.5 bc	0.0 d
SD	-	Ethephon	9.4 c	10.0 a	0.3 d
SD	-	Uniconazole	7.9 c	11.5 a	4.2 b
SD	+	Control	11.9 b	6.8 bc	0.0 d
SD	+	Ethephon	12.5 b	5.7 cd	0.0 d
SD	+	Uniconazole	7.8 c	10.8 bc	3.7 b
LD	-	Control	15.0 a	4.0 de	0.0 c
LD	-	Ethephon	12.4 b	8.1 b	0.4 d
LD	-	Uniconazole	7.9 c	11.2 a	9.3 a
LD	+	Control	16.1 a	2.3 e	0.0 d
LD	+	Ethephon	14.4 a	3.7 de	0.0 d
LD	+	Uniconazole	12.1 b	6.0 c	8.3 a

Z Data corrected from the lst node to the 20th node of main shoot.
Y - = Nondefoliation, + = Defoliation.
X Means within columns with different letter are significanty at the 0.05 probability level.

Table 4. Effects of photoperiod, defoliation and growth regulators on number of nodes with staminate and pistillate flowers in 'Rensei' cucumber.[Z]

Photo-period	Defoliation[Y]	Growth regulator	Number of nodes with staminate flower	Number of nodes with pistillate flower
SD	-	Control	0.0 c[X]	18.7 a
SD	-	$AgNO_3$	0.8 c	18.9 a
SD	-	GA_3	0.4 c	15.1 de
SD	+	Control	0.0 c	18.0 ab
SD	+	$AgNO_3$	3.8 b	15.8 cd
SD	+	GA_3	0.0 c	13.6 ef
LD	-	Control	0.2 c	17.9 a
LD	-	$AgNO_3$	5.2 a	16.7 bc
LD	-	GA_3	0.2 c	10.1 g
LD	+	Control	0.4 c	17.7 ab
LD	+	$AgNO_3$	5.0 ab	15.8 cd
LD	+	GA_3	0.1 c	10.3 g

Z Data corrected from the lst node to the 20th node of main shoot.
Y - = Nondefoliation, + = Defoliation.
X Means within columns with different letter are significanty at the 0.05 probability level.

1944). Cantliffe (1981) reported that photoperiod had no effect on sex expression in cucumber and gherkin. The present results showed that the influence of photoperiod on sex expression depended on the genetic background. The SD treatment promoted pistillate flower formation and suppressed staminate flower formation in 'Sagami-hanjiro' and 'Otone No. 1' cucumber. The LD treatment had the reversed effect. The photoperiod had no effect on sex expression in 'Rensei' cucumber.

The defoliation raised position of the node of the first flower, and reduced number of pistillate flowers, especially under SD. These results indicate that some substances in leaves possibly influence floral bud differentiation and sex expression. Defoliation nullified the effects of ethephon and uniconazole on increasing number of pistillage flowes in 'Otone No. 1' and 'Sagami-hanjiro'. The defoliation also promoted the effect of GA_3 in increasing number of staminate flowers. The results suggest a possible relationship between some substance(s) produced in leaves and growth regulators in sex expression of cucumber. Takahashi *et al* (1982) found that the number of pistillate flowers in cucumber increased markedly when they were grafted onto *Sicyos angulatus* donors which had leaves induced by shortday. It was that the some substances from leaves may promote transformation of flower sex from staminate to bisexual and then to pistillate flower (Saito, *et al.*, 1988; Takahashi *et al.*, 1982).

The present study showed that ethephon increased number of pistillate flowers and decreased staminate flowers. The same effect of ethylene has been previously elucidated by other workers (Augustine *et al.*, 1973; lwahori *et al.*, 1970). All staminate flower buds that developed after spraying with ethephon become abortive, and then the secondary primordia develop into functional pistillate flowers in *Cucumis pepo* (Hume and Lovell, 1983).

Uniconazole induced bisexual flowers in 'Otone No. 1', although ethephon never induced bisexual flowers. Uniconazole inhibits the metabolic process of the C_{19}-methyl group in kaurene to the C_{19}-carboxyl group in kaurenoic acid and inhibits the microsomal oxdation of kaurene, kaurenol and kaurenal in *cucurbita maxima* (Izumi *et al.*, 1984). Thus ethephon and uniconazole have different roles in sex expression, although they have the same effect in inducing pistillate flower formations.

In gynoecious 'Rensei', both $AgNO_3$ and GA_3 decreased number of pistillate flowers. $AgNO_3$ decreased number of pistillate flowers and increased number of staminate flowers while GA_3 decreased number of pistillate flowers and induced blind nodes. Silver ion inhibits ethylene biosynthesis (Beyer, 1976), and reduced level of endogenous ethylene may have promoted the production of staminate flowers. GA_3 had no effect on ethylene evolution (Atsmon and Tabbak, 1979). Therefore, GA_3 and $AgNO_3$ suppressed pistillate flower formation probably through different mechanism.

In cucumber flower bud develops as a bisexual flower and later only one of female or male organ develops (Atsmon and Galun, 1962). Fuchs et al. (1977) indicated that the reversion of pistillate flower to staminate flower does not occur by gibberellin, but staminate flower bud is induced as adventitious flower bud next to the original pistillate flower. It was observed, in the present work, that the node of the change from pistillate to staminate flower was different between monoecious and gynoecious cultivars. GA_3 promoted male tendency in monoecious 'Sagami-hanjiro' by reversing pistillate flower to staminate flower while it caused abortion of pistillate flowers in gynoecious 'Rensei'.

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