Studies on the growth behaviour of cucumber, Cucumis sativus L. I. : The types of sex expression and its sensitivity to various daylength and temperature conditions

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Studies on the growth behaviour of cucumber, *Cucumis sativus* L. I.

The types of sex expression and its sensitivity to various daylength and temperature conditions[1]

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Sex expression in cucumber is well known to be changeable by the daylength and the temperature condition. Types of sex expression and the sensitiveness to the daylength and temperature are considered to be governed primarily by the gametic constitution of the plant. Nitsch et al.[10] with Acorn squash reported the gradual shifting from maleness to femaleness as expressed by the change of the ratio of male flowers to female flowers. In their studies the order of those distinct transformation of phases seemed invariable but the onset and duration of those respective phases could be artificially controlled by the change of the light-temperature complex. Shifriss and Galun[13] in cucumber, and Hopp[6] in Butternut squash, reported on the existence of situation where, as a varietal characteristic, the position of the first pistillate flower on the main stem expressed by the number of nodes prior to this flower was quite constant under a given set of conditions.

In Japan, a number of studies on the sex expression of cucumber cultivars have been done with due regard to its sensitivity to daylength and temperature, and they have contributed to the practical breeding programs and, in consequence, to the development of croping system of cucumbers.[1,2,3,4,5,7,8,9] Since the effects of light and of temperature on the sex expression seem to be complicated with each other, the analysis of the sensitivity of such expression to daylengths and to temperatures is very difficult under the natural climatic conditions. In order to raise many cultivars, which are well adapted for the advancement of diver-

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gent croping systems, it seems quite necessary to begin with the detailed genecological studies on the problems of sex expression. The present authors have engaged on the studies to make clear the sex expression, the development of the nodal phase of staminate and pistillate flowers and its mode of variation, using 25 cultivars, in total, which belong to 4 different ecotypes, i. e., South Chinese variety-complex, North Chinese variety-complex, Hibrid variety-complex and European variety-complex (Fig. 1). Various combinations of the daylength and temperature in the Phytotron at Kyushu University were applied throughout. Climatic conditions in these experiments have been accomplished by varying the light-temperature comlex.

Materials and Methods

Cucumber cultivars used are listed in Table 1. Three to five cultivars were used for each experiment. Each plot of the experiment was filled with 4-6 plants of each cultivar. As the growing periods varied with the cultivars, and also as the condition and duration of treatment were not the same, "Kurume-ochiai No. 2" was used for the check variety throughout the experiments. Characteristics of each cultivar were observed and compared with this check variey. The origin and lineage of Japanese cucumbers are given in Fig. 1 in brief. All the experiments were performed in the Phytotron attached to Faculty of Agriculture, Kyushu University. After opening the cotyledons the seedlings were transplanted and grown in 10-x 10-cm cans filled with sand (Exp. V-IX), with the medium consisting of equal quantity of sand and perlite (Exp. III and IV), or with that of perlite and vermiculite (Exp. I and II), and watered with the Hyponex 1000 times solution. All plants received 7 hr of sun-light through glass. Additional illumination, when necessary, was given as the artificial light from fluorescent tubes giving approximately 600 lux at the plant level. During the 7 hr of sun-light and its before and after 30 minutes, plants were subjected to a given temperature refered to as "day temperature" in Table 2, and the temperature during the remaining 16 hr are called "night temperature" regardless of whether or not the additional light was given during this period. The temperature was changed automatically. After treatments plants were transplanted in the open field or removed into the greenhouse. The plants in low temperatures were kept growing more than 30 days until each plant had at least 4 expanded leaves.

Results

It was confirmed that the after-effect of the treatments, i. e., low temperature and short-day, on the sex expression of the seedlings was

Table 1. Experimental Design (1). Cucumber cultivars used.

Experiment	Cultivars	Supplied from	Origin and history
I	Kurume-ochiai No. 2	Kurumé Br. of Hort. Res. Sta.	Offshoot of "Saitama-ochiai"
	Natsu-fushinari	〃	
	Chôjitsu-ochiai No. 2	〃	F_1 (Natsu-fushnairi× Kurume-ochiai No. 2)
II	Kurume-ochiai No. 2	〃	
	Sagami-hanjiro	Kanagawa Pref. Agr. Exp. Sta.	
	Ao-fushinari	Tokyo Noko Univ.	
	Izumi-haru	Mr. Izumi Makimura	
	Suyo	Kurume Br. of Hort. Res. Sta.	
III	Kurume-ochiai No. 2	〃	
	Daisen-fushinari No. 1	Osaka Pref. Agr. Exp. Sta.	
	Disen-kema	〃	
	Hyuga No. 2	Kurume Br. Hort. Res. Sta.	
IV	Kurume-ochiai No. 2	〃	
	Santo	〃	
	Natsu-fushinari	〃	
	Chikanari-santo	〃	F_1(Natsu-fushinari × Santō)
V	Kurume-ochiai No. 2	〃	
	Jibai-ao	〃	Offshoot of Sunazu (1959)
	Peking-suyo	〃	Peking Nation. Hort. Farm
VI	Kurume-ochiai No. 2	〃	
	Higan-fushinari	〃	
	Shogoin	Takayama Seed Comp.	(1960)
	Improved Long Green	Kurume Br. Hort. Res. Sta.	Wageningen Hort. Bre. Sta.
VII	Kurume-ochiai No. 2	〃	
	Kurume-ochiai No. 1	〃	Offshoot of Sekino-ochiai
	Natsu-fushinari	〃	
	MSU 713-5	〃	Univ. of Michigan (1961)
VIII	Kurume-ochiai No. 2	〃	
	Baby	〃	
	Delikatess	〃	Gebruden Düppe Comp. (1960)
	Lemon	〃	
IX	Kurume-ochiai No. 2	〃	
	Le Généreux	〃	Vilmorin-Andrieux, Paris
	Galakhovskij	〃	U.S.S.R. Agr. Res. Sta.
	Nezhinskij mestnyj	〃	〃
	Klinskij mestnyj	〃	〃

Table 2. Experimental Design (2). Treatments and duration.

Exp.	Sowing date	No.	Treatment Photo-period[2]	Treatment Temperature Day-Night °C	Duration (days after germination)[1]	Condition after treatment
I	Nov. 21, 1958	1	L, S	25—25	5—35	25—20 °C in Phytotron
		2	〃	25—20	〃	
		3	〃	25—17	〃	
		4	〃	20—20	〃	
II	Jan. 22, 1960	1	L, S	25—20	7—37	Greenhouse
		2	〃	25—15	〃	
		3	〃	25—13	〃	
III	Mar. 17, 1961	1	L, S, N	27—22	7—32	Greenhouse
		2	〃	22—17	〃	
		3	〃	17—12	〃	
IV	Sept. 22, 1961	1	L, S, N	27—22	7—32	Greenhouse
		2	〃	22—17	〃	
		3	〃	17—12	〃	
V	June 1, 1962	1	L, S	25—22	7—34	Field
		2	〃	20—20	〃	
VI	Nov. 8, 1962	1	L, S	30—25	7—35	Greenhouse
		2	〃	25—20	〃	
		3	〃	20—15	〃	
VII	Feb. 14, 1963	1	L, S	30—25	7—37	30—25 °C in Phytotron
		2	〃	25—20	〃	
		3	〃	20—15	〃	
VIII	Dec. 29, 1963	1	L, S, N	30—25	7—48	30—25 °C in Phytotron
		2	〃	25—20	〃	
		3	〃	20—15	〃	
IX	Feb. 2, 1964	1	L, S	30—25	7—38	30—25 °C in Phytotron
		2	〃	25—20	〃	
		3	〃	20—15	〃	

1) Plants were grown in each plot from -th to -th day after germination.
2) All plants received 7 hr of sun light from 09: 30 to 16: 30
L : Long day (7 hr of sun light plus 7 hr of artificial light).
S : Short day (7 hr of sun light).
N : Natural daylength.

unable to be detected at the end of ca. 30 days. For instance, "Kurume-ochiai No. 2" (Fig. 2, Exp. V) showed that the pistillate promotive effect by the low temperature and short-day treatment became to be lost with the nodes situated at the 17 th or 18 th because of accepting the high temperature and long-day in the field after the treatment. It was thought that the nodes which could receive the effect of treatment were different with the ages of seedlings. In these experiments the seedlings were treated by the low temperature and short-day until the first 4 leaves got open. The present observation and counting of the nodes provided with pistillate flower were made until just the 15 th node along the main stem. Whether the monoecious expression altered to the gynoecious on the upper nodes or not was estimated by the results obtained on the other experiments carried out in the open field. The data were compiled in Tables 4-12.

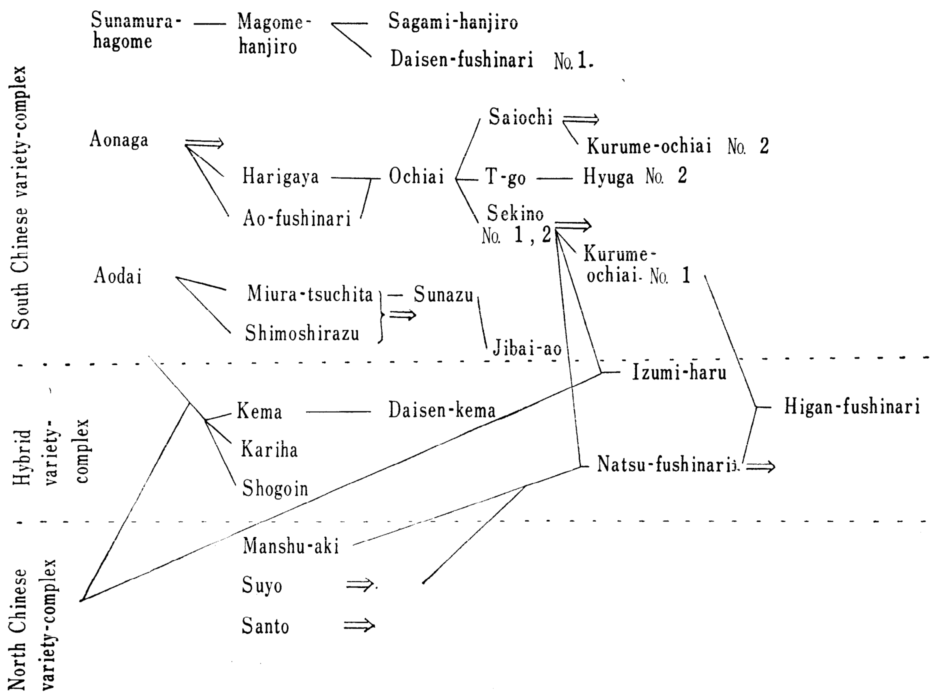


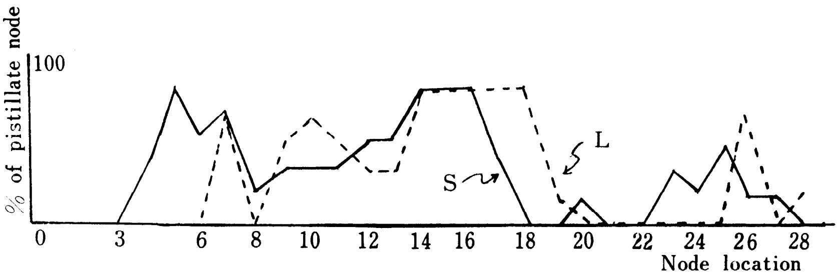
Fig. 1. Origin and lineage of various cucumbers in Japan.

1. Types of sex expression

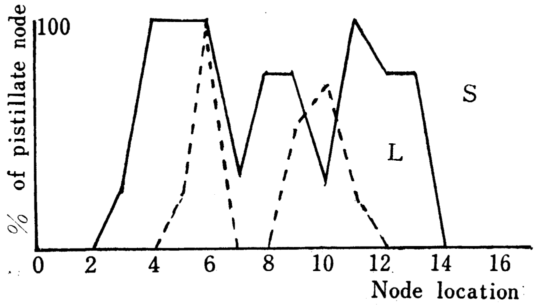
Throughout the experiments, it was obtained that not only the ability producing pistillate flowers and its sensitivity to the low temperature and short-day conditions but also the types of sex expression, i.e., the arrangement of the male and female flowers on the main stem appeared definitely different hereditarily from cultivar to cultivar. Thus the cultivars examined could be duly classified into the following 4 types.

(a) Monoecious type

Some flowers were pistillate and others were staminate. The distal part of stem tended to increase the pistillate nodes, but did not show the gynoecious state. The following cultivars were assigned for this type:



A) Kurume-ochiai No. 2 (Exp. V-2)



B) Kurume-ochiai No. 2 (Exp. VIII-2)

Fig. 2. Diminution of the pistillate promoting effect induced by short-day and low temperature treatment through the natural daylength and high temperature.

i) Varieties producing the pistillate flowers on a large number of nodes: Kurume-ochiai No. 2 (Tables 4–11), Sūyō (Table 5), Izumiharu (Table 5), Santō (Table 7), Peking-Sūyō (Table 8), Jibai-ao (Table 8), Klinskij mestnyj (Table 12), Nezhinskij mestnyi (Table 12) and Galakhovskij (Table 12).

ii) Varieties producing the pistillate flowers on a few nodes: Daisenkema (Table 6), Improved Long Green (Table 9), Baby (Table 11), Delikatess (Table 11) and Le Généreux (Table 12).

Table 3. Number* of expanded leaves at the end of the treatment.

Exp.	Cultivars	Treatment No.	L	S
I	Kurume-	1	6.2	6.0
	ochiai No. 2	2	6.0	5.8
		3	4.3	4 5
		4	4.2	3.8
	Natsu-fushi	1	5.8	5.5
	nari	2	4.2	4.7
		3	4.1	4.7
		4	3.5	3.8
	Chojitsu-	1	6.4	6.4
	ochiai No. 2	2	5.0	4.8
		3	4.0	4.5
		4	3.8	3.8
II	Kurume-	1	5.0	5.8
	ochiai No. 2	2	4.0	4.2
		3	3.0	4.0
	Sagami-	1	5.0	5.0
	hanjiro	2	4.7	4.8
		3	4.0	4.0
	Ao-fusinari	1	6.0	6.0
		2	5.0	5.8
		3	4.5	4.5
	Suyo	1	6.0	6.0
		2	4.8	4.8
		3	4.5	4.2
	Izumi-haru	1	4.3	4.8
		2	3.5	4.0
		3	3.0	3.5
III	Kurume-	1	6.0	6.3
	ochiai No. 2	2	4.2	4.5
		3	2,7	2.0
	Daisen-	1	7.7	7.5
	fushinari No.1	2	5.5	5.3
		3	3.3	2.8
	Daisen-Kema	1	9.0	8.5
		2	5.3	5.7
		3	3.0	2.7
	Hyuga No. 2	1	7.8	8.5
		2	5.0	5.7
		3	3.3	3.0
IV	Kurume-	1		6.4
	ochiai No. 2	2	4.2	4.6
		3	2.6	2.6
	Santo	1		6.6
		2	4.4	5.2
		3	2.4	2.4
	Natsu-	1		5.6
	fushinari	2	5.4	5.0
		3	2.0	2.0
	Chikanari-	1		7.4
	santo	2	5.0	5.0
		3	2.2	2.6
V	Kurume-	1	6.0	6.2
	ochiai No. 2	2	4.0	4.0
	Jibai-ao	1	8.0	7.0
		2	5.3	4.3
V	Peking-suyo	1	8.2	7.0
		2	5.0	4.0
	Santo	1	8.0	7.0
		2	5.8	4.2
VI	Kurume-	1	9.8	8.5
	ochiai No. 2	2	7.0	7.0
		3	3.5	4.0
	Shogoin	1	12.5	10.5
		2	8.8	8.5
		3	5.0	4.3
	Higan-	1	8.2	7.8
	fushinari	2	6.0	6.3
		3	4.0	4.0
	Improved Long	1	12.3	10.5
	Green	2	8.8	9.0
		3	5.0	5.0
VII	Kurume-	1	7.0	6.5
	ochiai No. 2	2	5.2	5.0
		3	2.7	2.0
	Kurume-	1	7.3	6.7
	ochiai No. 1	2	5.3	4.8
		3	3.3	2.7
	Natsu-	1	8.0	7.0
	fushinari	2	5.5	4.5
		3	2.3	2.3
	MSU 713-5	1	7.5	7.0
		2	6.4	5.3
		3	2.2	2.5
VIII	Kurume-	1	7.0	6.0

Exp.	Cultivars	Treatment No.	L	S	Exp.	Cultivars	Treatment No.	L	S
	ochiai No. 2	2	5.8	5.0			3	3.0	2.5
		3	2.0	2.0		Le Généreux	1	10.5	9.3
	Baby	1	7.8	7.3			2	6.8	6.5
		2	5.2	5.1			3	3.0	2.5
		3	2.3	2.2		Galakhovskij	1	10.5	10.0
	Delikatess	1	8.3	9.5			2	7.5	6.8
		2	5.8	5.3			3	3.0	2.5
		3	2.3	2.4		Nezhinskij	1	11.0	10.5
	Lemon	1	9.0	8.5		mestnyj	2	8.8	7.0
		2	5.8	5.6			3	3.8	3.5
		3	2.3	2.5		Klinskij	1	10.3	8.3
IX	Kurume-	1	9.0	8.8		mestnyj	2	7.3	6.3
	ochiai No. 2	2	5.8	5.0			3	3.8	3.5

* Means of 4—6 individuals.

Table 4. Sex expressions in cucumbers (1). From experiment I.

Cultivars	Treatment No.	First pistillate node[1)]		Number of pistillate nodes until 15 th node		First node[1)] in the fixed pistillate phase	
		L	S	L	S	L	S
Kurume-ochiai	1	12.3	7.7	1.7	3.8	—	—
No. 2	2	8.0	5.2	4.7	7.2	—	—
	3	7.0	4.8	6.0	9.8	—	—
	4	5.3	3.8	6.3	10.3	—	—
Natsu-fushinari	1	5.3	3.2	10.7	12.3	5.3	3.2
	2	3.3	3.2	11.8	12.5	5.3	4.0
	3	3.0	2.8	12.4	13.0	3.6	3.5
	4	3.0	2.8	13.0	13.3	3.0	2.8
Chojitsu-	1	7.4	4.7	5.2	9.7	13.4	9.8
ochiai No. 2	2	3.8	3.7	10.2	11.2	10.4	6.7
	3	4.2	2.7	11.4	12.7	5.2	5.0
	4	3.5	2.8	11.5	12.8	5.0	2.8

1) Denoting the node by its order on the main stem, counted from the proximal base of stem.

Table 5. Sex expressions in cucumbers (2). From experiment II.

Cultivars	Treatment No.	First pistillate node		Number of pistillate nodes until 15th node		First node in the fixed pistillate phase	
		L	S	L	S	L	S
Kurume-ochiai No. 2	1	5.7	5.7	5.2	6.2	—	—
	2	3.7	3.0	8.5	11.5	—	—
	2	4.2	3.3	9.0	10.5	—	—
Sagami-hanjiro	1	6.0	6.0	3.7	6.5	14.2	12.5
	2	4.8	4.2	10.8	11.3	5.3	4.2
	3	4.8	3.5	10.8	11.7	6.0	4.7
Ao-fushinari	1	3.0	3.2	5.2	9.2	15.2	13.5
	2	2.7	2.7	11.7	12.7	7.0	4.0
	3	3.2	3.0	12.5	13.0	4.3	3.0
Suyo	1	4.8	5.2	3.5	2.8	—	—
	2	4.8	5.2	6.2	5.5	—	—
	3	3.8	3.7	7.1	6.8	—	—
Izumi-haru	1	8.0	7.7	1.8	2.3	—	—
	2	5.7	4.3	3.3	3.8	—	—
	3	5.3	4.8	4.8	3.7	—	—

Table 6. Sex expressions in cucumbers (3). From experiment III.

Cultivars	Treatment No.	First pistillate node			Number of pistillate nodes until 15th node			First node in the fixed pistillate phase		
		L	S	N*	L	S	N*	L	S	N*
Kurume-ochiai No. 2	1	9.7	6.3	12.2	2.8	4.8	11.5	—	—	—
	2	4.8	4.4	5.3	7.5	7.6	5.0	—	—	—
	3	3.0	2.8	3.0	9.3	10.5	9.6	—	—	—
Daisen-fushinari	1	—	12.0	19.6	0	1.5	0	—	16.3	—
	2	11.3	7.5	11.8	3.8	7.0	1.8	12.3	9.0	—
	3	6.4	5.0	6.4	5.5	8.0	6.0	**	**	**
Daisen-kema	1	—	15.2	—	0	0.7	0	—	—	—
	2	—	—	16.5	0.3	0.7	0.3	—	—	—
	3	12.2	10.5	9.6	0.8	0.7	1.4	—	—	—
Hyuga No. 2	1	14.5	11.0	12.0	0.7	1.5	0.3	**	**	**
	2	6.3	5.6	6.6	**	**	2.6	**	**	**
	3	**	**	**	**	**	**	**	**	**

* Natural daylength.
** Observation was impossible because of self topping.

Table 7. Sex expressions in cucumbers (4). From experiment IV.

Cultivars	Treatment No.	First pistillate node			Number of pistillate nodes until 15th node			First node in the fixed pistillate phase		
		L	S	N	L	S	N	L	S	N
Kurume-ochiai	1		10.4			3.2			—	
No. 2.	2	7.2	5.4	5.6	4.3	5.6	6.2	—	—	—
	3	5.0	3.3	4.8	4.2	6.3	4.4	—	—	—
Santo	1		7.2			2.4			—	
	2	5.6	5.8	4.2	3.6	4.0	4.2	—	—	—
	3	3.0	3.0	3.0	7.3	7.5	6.4	—	—	—
Natsu-fushinari	1		3.2			12.0			4.8	
	2	3.2	3.0	2.0	13.0	12.8	14.0	3.0	2.8	2.0
	3	2.7	2.0	2.2	13.3	14.0	13.8	2.7	2.0	2.2
Chikanari-santo	1		4.4			4.5			—	
	2	3.5	3.7	3.2	6.5	8.5	9.0	14.2	11.3	13.0
	3	3.2	3.0	2.5	8.6	9.2	9.8	*	*	*

* Self topping.

Table 8. Sex epressions in cucumbers (5). From experiment V.

Cultivars	Treatment No.	First pistillate node		Number of pistlilate nodes until 15th node		First node in the fixed pistillate phase	
		L	S	L	S	L	S
Kurume-ochiai	1	12.3	8.5	0.8	2.5	—	—
No. 2.	2	7.5	4.8	4.5	6.5	—	—
Jibai-ao	1	11.8	8.8	1.2	1.5	—	—
	2	10.5	7.3	1.7	2.5	—	—
Peking-suyo	1	13.5	13.8	0.8	0.7	—	—
	2	12.0	10.2	1.2	1.5	—	—

(b) Mono-gynoecious type

The proximal part of the stem showed the monoecious state and the distal part the gynoecious one. The followings were assigned for this type: Ao-fushinari (Table 5), Sagami-hanjiro (Table 5), Daisen-fushinari (Table 6), some of Shōgoin (Table 9), Kurume-ochiai No. 1 (Table 10), and the F_1 hybrids between the mono-gynoecious and gynoecious types belonged to this type, as shown in Chojitsu-ochiai No. 2 (Table 4) and Chikanari-santo (Table 7).

(c) Gynoecious type

The flowers were usually pistillate, but a few staminate ones were produced under certain definite environment: Natsu-fushinari (Tables 4,

Table 9. Sex expressions in cucumbers (6). From experiment VI.

Cultivars	Treatment No.	First pistillate node		Number of pistillate nodes until 15 th node		First node in the fixed pistillate phase		Gynoecious plants per individuals	
		L	S	L	S	L	S	L	S
Kurume-ochiai	1	—	16.0	0	0.5	—	—	0	0
No. 2	2	13.2	8.0	2.0	5.7	—	—	0	0
	3	6.8	5.2	4.3	6.8	—	—	0	0
Shogoin	1	—	7.6	2.0	5.7	—	—	1/6	0
	2	4.8	4.6	8.3	10.4	—	—	1/6	1/6
	3	3.2	3.0	12.5	12.3	—	—	3/6	4/6
Higan-fushinari	1	2.0	2.2	12.8	1.2	6.0	13.5	3/6	0
	2	2.0	2.0	11.5	10.5	6.3	6.8	0	0
	3	2.0	2.0	10.4	12.3	7.0	4.5	0	0
Improved Long	1	—	—	0	0	—	—	0	0
Green	2	—	—	0	0	—	—	0	0
	3	—	—	0	0	—	—	0	0

Table 10. Sex expressions in cucumbers (7). From experiment VII.

Cultivars	Treatment No.	First pistillate node		Number of pistillate nodes until 15 th node		First node in the fixed pistillate phase	
		L	S	L	S	L	S
Kurume-ochiai	1	—	16.3	0	0.2	—	—
No. 2	2	14.8	7.7	0.8	3.7	—	—
	3	6.3	3.5	3.5	9.3	—	—
Kurume-ochiai	1	—	17.3	0	0.3	—	—
No. 1	2	13.7	5.8	0.8	4.2	—	13.3
	3	6.2	4.5	4.0	9.2	—	7.8
Natsu-fushi nari	1	2.7	3.5	10.2	11.3	8.5	6.0
	2	2.5	3.0	12.2	12.8	3.5	3.7
	3	2.0	2.0	14.0	14.0	2.0	2.0
MSU 713-5	1	2.0	2.0	14.0	14.0	2.0	2.0
	2	2.0	2.0	14.0	14.0	2.0	2.0
	3	2.0	2.0	14.0	14.0	2.0	2.0

7, and 10), some of Shōgoin (Table 9), Higan-fushinari (Table 9), and MSU 713-5 (Table 10).

(d) Andro-monoecious type

The type which has both staminate and hermaphroditic flowers. Hermaphroditic flowers on "Lemon" were not observed until the 20th node on the main stem (Table 10).

Table 11. Sex expressions in cucumbers (8). From experiment VIII.

Cultivars	Treatment No.	First pistillate node			Number of pistillate nodes until 15th node			First node in the fixed pistillate phase		
		L	S	N	L	S	N	L	S	N
Kurume-ochiai	1	—	15.7	—	0	0.5	0	—	—	—
No. 2	2	11.3	7.0	8.3	1.8	4.0	3.0	—	—	—
	3	6.5	4.5	6.0	4.5	9.0	7.8	—	—	—
Baby	1	—	—	—	0	0	0	—	—	—
	2	10.8	7.0	11.0	1.0	1.7	1.0	—	—	—
	3	7.3	5.3	5.5	2.3	3.0	4.2	—	—	—
Delikatess	1	—	—	—	0	0	0	—	—	—
	2	16.8	9.0	13.3	0	1.8	0.8	—	—	—
	3	7.0	8.3	8.0	1.0	2.3	0.5	—	—	—
Lemon	1	—	—	—	0	0	0	—	—	—
	2	—	—	—	0	0	0	—	—	—
	3	—	—	—	0	0	0	—	—	—

Table 12. Sex expressions in cucumbers (9). From experiment IX.

Cultivars	Treatment No.	First pistillate node		Number of pistillate nodes until 15th node		First node in the fixed pistillate phase	
		L	S	L	S	L	S
Kurume-ochiai	1	—	—	0	0	—	—
No. 2	2	11.8	11.0	2.0	3.0	—	—
	3	7.3	5.5	6.5	7.8	—	—
Le Généreux	1	—	—	0	0	—	—
	2	—	—	0	0	—	—
	3	11.3	8.8	0.8	2.0	—	—
Galakhovskij	1	—	—	0	0	—	—
	2	—	14.0	0	0.3	—	—
	3	13.5	10.3	1.0	1.0	—	—
Nezhinskij	1	—	15.8	0	0.5	—	—
mestnyj	2	12.5	10.5	0.3	1.0	—	—
	3	8.4	8.7	1.0	0.8	—	—
Klinskij	1	14.5	15.3	0.8	0.5	—	—
mestnyj	2	8.8	7.8	2.3	1.0	—	—
	3	6.0	6.3	2.0	1.8	—	—

2. Pistillate flower formation and its sensitivity to environmental conditions

(a) Sensitivity to the temperature

The promotive effect of low temperature for the pistillate flower development could not be observed on the cultivars, Improved Long Green (Table 9), Lemon (Table 10), MSU 713-5 (Table 10), and Higan-fushinari (only in long-day) (Table 9). Most cultivars except above ones, regardless of their origin and lineage, were facilitated for the formation of pistillate flowers by low temperatures.

(b) Sensitivity to the daylength

A definite differentiation of the sensitivity was observed as shown below. It seems to be closely connected with the origin and lineage of cultivars.

i) Short-day sensitives; the pistillate flower development was promoted under the short-day condition: Kurume-ochiai No. 2 (Tables 4-11), Sagami-hanjiro (Table 5), Ao-fushinari (Table 5), Daisen-fushinari (Table 6), Jibai-ao (Table 8), Kurume-ochiai No. 1 (Table 10), Baby (Table 11), Le Généreux (Table 12), and Delikatess (Table 11). Cultivars which are considered to belong to the South Chinese variety-comlpex and accliminated in Japan in the South Chinese course of generations come to this category.

ii) Daylength insensitives; the sex differentiation was not affected by the daylength: Sūyō (Table 5), Izumi-haru (Table 5), Daisen-kema (Table 6), Santō (Table 7), Natsu-fushinari (Tables 4, 7 and 10), Chikanari-santō (Table 7), Peking-sūyō (Table 8), some of Shōgoin (Table 9), Improved Long Green (Table 9), MSU 713-5 (Table 10), Klinskij mestnyj (Table 12), Nezhinskij mestnyj (Table 12), and Galakhovskij (Table 12), Cultivars which belong to the North Chinese variety-complex and to the Russian varieties and which are considered to have been established in those high latitude areas come to this type. Varieties raised through the hybridization, namely, "Daisen-kema," "Shōgoin," "Natsu-fushinari" and "MSU 713-5" are still containing genotypes originated from the North-Chinese varieties. "Chōjitsu-ochiai No. 2" which is the F_1 hybrid between "Natsu-fushinari" (daylength insensitive) and "Kurume-ochiai No. 2" (short-day sensitive) shows slight short-day sensitiveness in general. The daylength insensitiveness looked like imperfect dominance in the F_1 hybrids. "Shōgoin" could be divided into the short-day monoecious type and the daylength insensitive gynoecious one.

iii) Long-day sensitives; the pistillate flowers development was promoted under the long-day and high temperature conditions. This was observed only on "Higan-fushinari." This cultivar was selected out of the hybrid strains between "Natsufushinari" and "Kurume-ochiai No. 1." Such a new form as "Higan-fushinari" had not been encountered in the past cucumber breeding. Hereditary behavior of this variety would be taken as an entirely new case.

Discussion

Most of our cucumbers are of monoecious. They have the characteristic to develop easily the pistillate flowers on the upper nodes instead of the staminate ones with the advance of growing and with the effective changes of environmental conditions. Such a characteristic of flower formation can be usually detected in the Japanese cultivars which were produced for the intensive culture and on which selections were advanced intensively with the aim to get much more pistillate flowers.

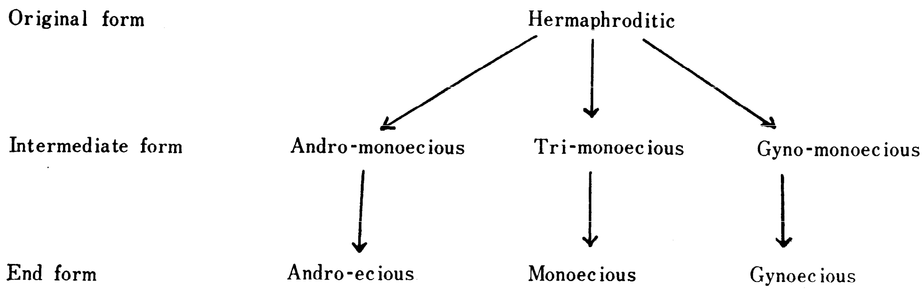


Fig. 3. The scheme of the evolution of sex expression, by Correns (1928), after Whitaker (1931).

Attaching importance to this hereditary tendency which provides pistillate flowers on the upper nodes, authors designated this type as "Mono-gynoecious type," distinguishing from the "Monoecious type" which does not turn to set only pistillate flowers even on the upper nodes under the natural climatic conditions. Sometimes plants which developed only pistillate flowers were found in cultivars such as "Shōgoin" and a certain North Chinese varieties. Since the offspring of this gynoecious form could be obtained by the Gibberellin treatment, the "Gynoecious type" was recognized as an independent type of sex expression, though it needs such an artificial measure to get seeds. Thus the types of sex expression became to be classified into four types including the "Andro-monoecious type" of cultivar "Lemon".[11] It may be natural to think the existence of the "Androecious type." It is out of thought, however, because such varieties will be thrown out of the cultural world. Moreover, there are no reports on the cucumber varieties of "Tri-monoecious type" and "Gyno-monoecious type" of sex expression.

Whitaker[14,15] supports the scheme of evolution of sex expression proposed by Correns on cucurbits. It is clear that the cucumber evolved from the hermaphroditic into the gynoecious form judging from the fact that each female flower develops through the bisexual stage. Doubtful is the opinion that each of gynoecious and monoecious form evolved through the gyno-monoecious and tri-monoecious one respectively. Most of the hermaphroditic flowers are found more or less maleformed, not showing any fertility. Fujieda et al.[3,4] did not encounter any hermaphroditic flowers during the processes of breeding the gynoecious cult. "Natsu-fushinari" and "Higan-fushinari." Neither did Peterson et al.[11,12] who bred "MSU 713-5." The F_1 hybrids between the mono-gynoecious and the momoecious types were mono-gynoecious, being rather strongly affected by the female producing ability of the monoecious type. The interpretation, that the above situation may depend on the accumulation of multiple factors which are destined for the pistillate flower formation, may be more probable than that to set up certain specific intermediate sex types for the formation of the gynoecious and the gyno-monoecious types, respectively.

The effect of temperatures on the sex expression in cucumbers was either observed just a slight or not with the cultivars such as "Improved Long Green" and "Lemon," which are definitely weak in their ability to produce pistillate flowers, and the typical gynoecious cultivars, i. e., "MSU 713-5", "Hgan-fushinari (in long day)" and "Natsu-fushinari." But the low temperature usually promoted the pistillate flower formation in other cucumber cultivars. Though the situations of the pistillate nodes are changeable by temperatures, the increasing-effect of low temperatures to the number of pistillate nodes is different in cultivars. The effect does not seem slight in the monoecious cultivars, in general.

There are many reports which support the short-day sensitiveness on the pistillate flower formation. Kumazawa et al.,[9] Itoh et al.[7] and Fujii et al.[5] showed that the extent of sensitiveness is rather different with varieties. Varieties which belong to the North Chinese variety-comlex and to the Russian variety-complex and as well as their hybrid forms did not show the short-day response of the sex expression, so that they would be duly taken as "Daylength insensitives."

The one thing which is very interesting is the sensitivity of the cultivar "Higan-fushinari" to the daylength. It showed the "Gynoecious" expression by low temperatures, the "Monoecious" one by high temperatures in the short-day, and remained at "Gynoecious" type by long-day even under the high temperature conditions. Thus the sensitivity to temperatures seems a simple phenomenon, and the insensitiveness is obtainable just in a few exceptional cultivars. Most of cucumber cultivars belong to the short-day sensitives and also to the daylength insensitives. Recent finding of the long-day sensitive cultivars "Higan-fushinari" may induce the change of our former knowledge that the pistillate flower differentiation is promoted exclusively by low temperatures and short-day environments. Table 13 shows various types of sex expressions and the sensitiveness to daylengths and temperatures on the cucumber cultivars examined.

Table 13. Classification of cucumber cultivars by the type of sex expression and the sensitivity to the temperature and the daylength.

Type of sex expression	Low temperature sensitive			Temperature insensitive
	Short-day sensitive	Daylength insensitive	Long-day sensitive	Daylength insensitive
Monoecious	Kurume-ochiai No. 2 Jibai-ao Baby Delikatess Hyuga No. 2	Suyo Izumi-haru Santo Peking-suyo		Improved Long Green
Mono-gynoecious	Sagami-hanjiro Ao-fushinari Daisen-fushinari No. 1 Kurume-ochiai No. 1 Shogoin	Chojitsu-ochiai No. 2 Chikanari-santo Daisen-kema		
Gynoecious		Natsu-fushinari Shogoin	Higan-fushinari	MSU 713-5
Andro-monoecious		Lemon		

Summary

1. Study on the sex expressions in cucumbers, *Cucumis sativus* L., the nodal phase of male and female flowers and its mode of variation has been performed under various combinations of the daylength and temperature in the Phytotron at Kyushu University.

2. 25 cultivars of cucumber from 4 ecotypes were used for this study.

3. The types of sex expression were divided into the following four types: a) Monoecious type; some flowers were female and others were male. The distal part of stem tended to increase the female nodes, but did not show the gynoecious state. b) Mono-gynoecious type; the proximal part of the stem showed the monoecious state and the distal part

the gynoecious one. c) Gynoecious type; the flowers were usually female. But a few male ones were produced under certain definite environment. d) Andro-monoecious type; the type which has both male and hermaphroditic flowers.

4. The promotive effect of low temperature for the female flower development could not observed on the cultivars, "Improved Long Green," "Lemon," "MSU 713-5" and "Higan-fushinari (only in long-day)." Most cultivars except above ones, regardless of their origin and formation, were faciliated for the formation of female flowers by low temperatures.

5. A definite differentiation of the sensitivity to the daylength was observed as following: a) Short-day sensitives; flower development was promoted by short-day. b) Daylength insensitives; the sex differentiation was not affected by the daylength. c) Long-day sensitives; female flower development was promoted under the long-day and high temperature conditions.

6. Cucumber cultivars used were classified with the types of sex expressions and the sensitiveness to daylengths and temperatures as shown in Table 13.

7. Cultivars which are considered to belong to the South Chinese variety-complex (See Fig. 1.) were low temperature and short-day sensitive.

8. Cultivars which belong to the North Chinese variety-complex (See Fig. 1.) and to the European one, i. e., "Klinskij mestnyj," "Nezhinskij mestnyj" and "Galakhovskij," were low temperature sensitive and daylength insensitive.

9. Cultivar "Higan-fushinari" showed the "Gynoecious" sex expression by low temperatures, the "monoecious" one by high temperature in short-day. It remained at "gynoecious" type by long-day even under the high temperature conditions.

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