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Geographic Variation of Flowering Response to Daylength in *Perilla frutescens* var. *frutescens* in East Asia

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ABSTRACT : We investigated the variations of the flowering response to daylength in *Perilla* crop (var. *frutescens*). Seventeen accessions of *Perilla* crop and one accession of weedy type of var. *crispa* from China, Korea and Japan were cultivated under three daylength conditions, i.e., short-days, natural daylength and long-days. Most accessions of *Perilla* crop from China, Korea and Japan were divided into three types, early maturing type, intermediate maturing type and late maturing type by their natural flowering habit. In most of the accessions used, the flowering habit was significantly accelerated by short-day conditions and was delayed by long-day conditions. All the accessions of *Perilla* crops flowered within 57 days under the 10 hrs light treatment, whereas they did not flower at all even at 170 days after sowing under the 16 hrs light treatment. Thus, this finding suggested that there is a relationship between the types of flowering response to daylength and the geographical distribution which determines the planting season in traditional cultivation practices of *Perilla* crops. Positive correlation was observed between days to flowering and plant height or internode number in both the short-day and natural daylength conditions. Whereas, correlation was negative between days to flowering and inflorescence length or floret number in natural daylength condition, but it was positive in the short-day condition. Therefore, the daylength condition is considered as the most important environmental factor for flowering habit and morphological characters of *Perilla* crops. Flowering habit is considered as an important key character for the study of geographical differentiation of *Perilla* crop in East Asia.

Keywords **:** *perilla*, flowering response to daylength, geographic distribution, differentiation

Perilla frutescens Britt. (Labiatae) is a self-fertilizing crop which is widely cultivated in East Asia, i.e. China, Korea and Japan. *Perilla* crop (var. *frutescens*; Ren in Chinese, Dlggae in Korean and Egoma in Japanese) has been an important crop there from ancient times. Although *Perilla* crops distribute only in East Asia, there is considerable variation in growth habit among their accessions (Lee and Ohnishi, 2001b). *Perilla* is generally cultivated as a summer crop and is basically a short-day crop. Sensitivity to daylength is the factor that determines its flowering time and the duration of the growing period. Yu (1974) and Cho *et al.* (1984) reported that different photoperiod treatments gave a significant effect on flowering of *Perilla*. Twelve hours of short photoperiod treatment could promote flowering, whereas 16 hours photoperiod treatment did not induce flower bud formation. Most accessions of *Perilla* crops from China, Korea and Japan were divided into three types, early maturing type (days to flowering < 100 days), intermediate maturing type (100 ≤ days to flowering ≤ 130 days) and late maturing type (days to flowering > 130 days) by their natural flowering habit (Lee and Ohnishi, 2001b). Latitude may be related with the geographical differentiation of cultivated and weedy types of var. *frutescens*.

Morphological differentiation of a species within its geographical distribution areas has been of considerable interest in the study of the evolution of species (Gould and Johnston, 1972; Wyatt and Antonovics, 1981). Divergence among accessions may occur as a result of microevolutionary changes in different environments. In addition, domestication is an evolutionary process through which domesticated plants become morphologically and physiologically divergent from their wild ancestors (Schwanitz, 1966; Harlan, 1992). The process of domestication has been generally associated with cultivation in controlled environments of plants originating from wild accessions (Harlan, 1992; Zohary and Hopf, 1993).

In the present study, we analyzed the variation of flowering response to daylength in cultivated var. *frutescens* to clarify its geographical differentiation. The correlations between days to flowering and morphological characters of *Perilla* accessions were also analyzed.

MATERIALS AND METHODS

The materials consisted of 18 accessions (17 cultivated

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Table 1. Accessions of *Perilla* crop used.

Code No.	Accession No.	Source of material		Type of flowering habit	Latitude of collection site
		Village, town or city	country		
1	CH1	Yongsheng, Yunnan	China	Late maturing	28 °N
2	CH2	Lijiang, Yunnan	China	Late maturing	27 °N
3	CH5	Dayao, Yunnan	China	Late maturing	25 °N
4	CH7	Menning, Sichuan	China	Late maturing	30 °N
5	CH8	Wenchuan, Sichuan	China	Late maturing	30 °N
6	KOR11	Cheju-shi, Cheju-do	Korea	Late maturing	33 °N
7	KOR40	Ulsan-shi, Kyongsangnam-do	Korea	Late maturing	35 °N
8	KOR3	Yang-yang-gun, Kangwon-do	Korea	Intermediate	38 °N
9	KOR7	Okchon-gun, Chungchongbuk-do	Korea	Intermediate	36 °N
10	JA2	Sannohe-gun, Aomori-ken	Japan	Intermediate	40 °N
11	JA3	Waga-gun, Iwate-ken	Japan	Intermediate	40 °N
12	JA4	Minamiaizu-gun, Fukushima-ken	Japan	Intermediate	37 °N
13	JA5	Chichibu-gun, Saitama-ken	Japan	Intermediate	36 °N
14	KOR18	Pochon-gun, Kyonggi-do	Korea	Intermediate	38 °N
15	KOR1	Miryang-shi, Kyongsangnam-do	Korea	Early maturing	35 °N
16	KOR6	Yechon-gun, Kyongsangbuk-do	Korea	Early maturing	36 °N
17	JA1	Kawanishi-gun, Hokkai-do	Japan	Early maturing	43 °N
18	JA8	Higashichikuma-gun, Nagano-ken	Japan	Early maturing	36 °N

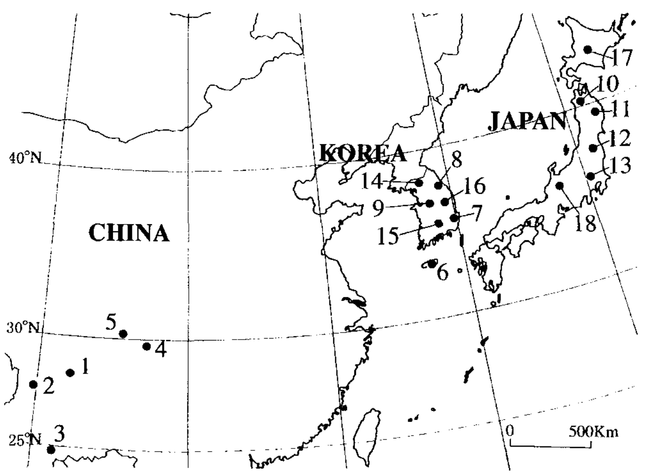

Fig. 1. Collection sites of 18 *Perilla* accessions in East Asia. See the Table 1 for code numbers.

landraces of var. *frutescens*, 1 weedy type of var. *crispa*) which were chosen to cover almost all the distribution regions in East Asia. Five accessions were from China, seven from Korea and six from Japan (see Table 1, Fig. 1). The seed samples which were obtained from the Plant Germplasm Institute, Kyoto University. We classified *Perilla* samples as early maturing type, intermediate type, and late maturing type according to their flowering habit in natural condition (Lee and Ohnishi, 2001b). The cultivation experiment was carried out in a glasshouse of the Plant Germplasm Institute in Kyoto located at latitude 35°N. Approximately fifteen seeds of each accession were sown in three nursery beds (18 accessions in a 33 × 53 × 11 cm^3 wooden box) on May 18, 2000. About one month later, four seedlings of each accession were transplanted to clay pots, one plant for each pot. All plants were grown without temperature control and fertilizer application under the following three daylength conditions, plots A, B and C.

Plot A, short-days (10 hrs light + 14 hrs darkness): pots were placed in a chamber where the automatic photoperiodic treatment was set to expose plants to 10 hrs of natural daylight and dark for 14 hrs from 6 p.m. to 8 a.m. An electric fan was continuously in motion for ventilation during the dark period.

Plot B, natural daylength: plants were exposed to the natural condition of light. The daylength at Kyoto, Japan was long at the beginning of the experiments (about 14 hrs light, 10 hrs dark) and gradually decreased to 10 hrs light, 14 hrs dark at the end of the experiment.

Plot C, long-days (16 hrs light + 8 hrs darkness): plants were exposed to natural daylight supplemented by artificial light from 6 : 30 p.m. to 8 p.m. and from 4 a.m. to 6 : 30 a.m. which was supplied by eight 40-watt fluorescent lamps placed at the height of 2 m above the pots (about 350 lux at the top of plant canopy).

At the appropriate growth stages, we examined five morphological characters (Table 2). Measurement of five morphological characters was practiced on four individuals for

Table 2. List of five characters analyzed.

Abbreviation	Character derivation	Time of measurement	Unit or Category
QN1	Days from seeding to flowering	50 % flowering	day
QN2	Plant height	at harvesting	cm
QN3	Number of knob	at harvesting	number
QN4	Length of the largest inflorescence	after harvesting	cm
QN5	Number of florets of the largest inflorescence	after harvesting	number

each accession, however, for some accessions only one to three individuals were used for the measurement due to plant growth failure.

Short-day and long-day treatments were started from the second day after sowing. The short-day treatment was ended at 54th days when all the strains had flowered. The long-day treatment was continued up to 170 days. However, under the 16 hrs long-day treatment, all the plants of all accessions of *Perilla* crops did not flower at all.

RESULTS

Table 3 shows the mean, standard deviation and range for the number of days to flowering and four morphological characters under different daylength conditions. In most accessions, flowering was significantly accelerated by the short-day treatment and was delayed by the long-day treatment (Table 3). All the accessions flowered within 57 days under the 10 hrs light treatment, in particular the accessions of early maturing type (KOR1, KOR6, JA1 and JA8) showed earlier flowering than the other types, although they did not flower at all even 170 days after sowing under the 16 hrs light treatment. In contrast, the accessions of late maturing type such as CH1, CH2 and CH5 showed extremely late flowering in plots A and B. The accessions of intermediate type showed various flowering time ranging from 33.5 days (JA2) to 50.5 days (JA3) in plot A.

Relationship between number of days to flowering and each morphological trait under the three daylength conditions were as follows (Table 3):

i) Plant height (QN2)-Under the short-day condition and natural condition, the early maturing accessions showed the shortest plant height, whereas the late maturing accessions were the tallest. Most of the intermediate accessions showed intermediate plant height between early and late maturing types. In plot C, most of the intermediate accessions were tall. In particular, the two accessions (KOR1, JA1) of early maturing type showed the tallest plant height. Thus, the plant height of *Perilla* crop can be easily changed by daylength condition.

ii) Number of internodes (QN3)-This character was significantly decreased by short-day treatment, and increased by long-day treatment. Particularly, in plot C, the number of internodes of the early maturing accessions (KOR1, JA1 and JA8) increased more than twice of that in plot B.

iii) Length of inflorescence (QN4) and number of florets (QN5)-The early maturing accessions (KOR1, JA1 and JA8) showed the longest inflorescence and the highest number of florets in nature daylength condition (plot B), except for one accession (KOR6). Whereas all accessions of the late maturing type (CH1, CH2, CH5, CH7, CH8, KOR11 and KOR40) showed longer inflorescence in plot A than in plot B, but showed a decreased number of florets in plot A than in plot B, except for two accessions (CH2, CH7). Most of intermediate accessions were not severely affected in these characters. The number of florets is more plentiful in the natural daylength condition than the short-day treatment.

Table 4 shows correlation coefficients between days to flowering and four morphological characters. Positive correlation was observed between days to flowering (QN1) and plant height (QN2), and between days to flowering (QN1) and internode number (QN3) in both the short-day and natural daylength conditions. Whereas correlation coefficient was significantly negative between days to flowering (QN1) and inflorescence length (QN4) and between days to flowering (QN1) and floret number (QN5) in the natural daylength condition, but it was positive in the short-day condition.

DISCUSSION

Most accessions of *Perilla* crops showed significant response to the daylength conditions. They did not flower at all under 16 hrs and flowered within 57 days under 10 hrs light treatment. These results indicated that the flowering habit of *Perilla* is significantly influenced by daylength. The three maturing types recognized in Lee and Ohinishi (2001b) were confirmed based on the flowering response to daylength. The early maturing type showed extraordinarily fast flowering both in plots A and B, whereas the late maturing type showed extraordinarily late flowering both in plots A and B. The intermediate type showed intermediate flowering habit between early and late maturing types both in plots A and B. Different maturity types of *Perilla* crops may result from differentiation by the geographical distribution

Table 3. Mean, standard deviation and range for the days to flowering and four morphological characters under different daylength conditions.

Code No.	Days to flowering (DAYS) Plot			Plant height (CM) Plot			Length of inflorescence (CM) Plot			Number of internode (NUMBER) Plot			Number of floret (NUMBER) Plot		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
1	55.8 ± 0.5	160.3 ± 0.5	170+	35.5 ± 1.3	173.8 ± 9.5	197.5 ± 3.5	15.8 ± 1.0	9.5 ± 0.6	*	4.3 ± 0.5	18.8 ± 1.0	19.0 ± 0.0	54.5 ± 1.9	60.5 ± 1.9	*
	(55.0-56.0)	(160.0-161.0)		(34.0-37.0)	(164.0-185.0)	(195.0-200.0)	(15.0-17.0)	(9.0-10.0)		(4.0-5.0)	(18.0-20.0)		(52.0-56.0)	(58.0-62.0)	
2	56.3 ± 1.0	157.8 ± 0.5	170+	46.8 ± 3.0	168.8 ± 2.5	192.5 ± 17.7	16.5 ± 3.0	9.0 ± 0.8	*	5.5 ± 0.6	18.5 ± 0.6	20.5 ± 0.7	57.0 ± 1.2	55.5 ± 1.9	*
	(55.0-57.0)	(157.0-158.0)		(43.0-50.0)	(166.0-172.0)	(180.0-205.0)	(14.0-20.0)	(8.0-10.0)		(5.0-6.0)	(18.0-19.0)	(20.0-21.0)	(56.0-58.0)	(54.0-58.0)	
3	56.8 ± 0.5	158.3 ± 0.5	170+	44.5 ± 7.7	164.0 ± 3.4	197.0 ± 3.5	13.0 ± 1.2	8.8 ± 1.0	*	5.3 ± 1.0	18.3 ± 0.5	20.5 ± 0.7	46.5 ± 1.9	57.5 ± 4.1	*
	(56.0-57.0)	(158.0-159.0)		(36.0-52.0)	(160.0-168.0)	(195.0-200.0)	(12.0-14.0)	(8.0-10.0)		(4.0-6.0)	(18.0-19.0)	(20.0-21.0)	(44.0-48.0)	(54.0-62.0)	
4	45.8 ± 0.5	148.5 ± 0.6	170+	47.8 ± 1.3	161.5 ± 4.4	205.0 ± 7.1	18.5 ± 1.7	9.5 ± 1.3	*	4.8 ± 0.5	18.3 ± 0.5	20.0 ± 0.0	55.5 ± 1.9	50.0 ± 5.4	*
	(45.0-46.0)	(148.0-149.0)		(46.0-49.0)	(156.0-166.0)	(200.0-210.0)	(16.0-20.0)	(8.0-11.0)		(4.0-5.0)	(18.0-19.0)		(54.0-58.0)	(46.0-58.0)	
5	42.8 ± 0.5	142.0 ± 0.8	170+	39.8 ± 1.7	168.3 ± 1.7	210.0 ± 7.1	14.3 ± 0.5	9.0 ± 1.2	*	4.5 ± 0.6	18.5 ± 0.6	21.0 ± 1.4	27.0 ± 1.2	57.0 ± 5.3	*
	(42.0-43.0)	(141.0-143.0)		(38.0-42.0)	(166.0-170.0)	(205.0-215.0)	(14.0-15.0)	(8.0-10.0)		(4.0-5.0)	(18.0-19.0)	(20.0-22.0)	(26.0-28.0)	(52.0-64.0)	
6	44.0 ± 0.0	131.0 ± 0.8	170+	37.0 ± 0.0	130.0 ± 1.6	144.0 ± 5.7	11.6 ± 1.1	8.5 ± 0.6	*	5.0 ± 0.0	15.5 ± 0.6	19.5 ± 0.7	38.0 ± 1.6	55.0 ± 2.6	*
		(130.0-132.0)			(128.0-132.0)	(140.0-148.0)	(10.0-12.5)	(8.0-9.0)			(15.0-16.0)	(19.0-20.0)	(36.0-40.0)	(52.0-58.0)	
7	51.3 ± 0.5	137.5 ± 1.0	170+	32.5 ± 1.9	129.3 ± 3.6	140.5 ± 6.4	13.3 ± 1.0	7.3 ± 0.5	*	4.8 ± 0.5	14.8 ± 0.5	16.0 ± 1.4	39.0 ± 2.6	44.5 ± 1.9	*
	(51.0-52.0)	(137.0-139.0)		(30.0-34.0)	(124.0-132.0)	(136.0-145.0)	(12.0-14.0)	(7.0-8.0)		(4.0-5.0)	(14.0-15.0)	(15.0-17.0)	(36.0-42.0)	(42.0-46.0)	
8	44.8 ± 0.5	119.8 ± 0.5	170+	27.0 ± 1.8	127.5 ± 5.3	210.0 ± 0.0	13.3 ± 1.5	9.3 ± 1.0	*	5.3 ± 1.0	15.8 ± 0.5	23.0 ± 0.0	32.0 ± 1.6	58.5 ± 4.4	
	(44.0-45.0)	(119.0-120.0)		(25.0-29.0)	(120.0-132.0)		(12.0-15.0)	(8.0-10.0)		(4.0-6.0)	(15.0-16.0)		(56.0-58.0)	(54.0-64.0)	
9	40.0 ± 0.0	123.5 ± 1.0	170+	24.5 ± 3.4	150.5 ± 4.0	175.0 ± 7.1	11.3 ± 1.5	7.8 ± 0.5	*	4.3 ± 0.5	16.3 ± 1.5	21.5 ± 0.7	31.0 ± 2.6	54.5 ± 1.9	*
		(123.0-125.0)		(20.0-28.0)	(145.0-154.0)	(170.0-180.0)	(10.0-13.0)	(7.0-8.0)		(4.0-5.0)	(15.0-18.0)	(21.0-22.0)	(28.0-34.0)	(52.0-56.0)	
10	33.5 ± 0.6	112.3 ± 0.5	170+	16.5 ± 1.9	148.0 ± 11.5	185.0 ± 7.1	6.5 ± 1.0	8.8 ± 0.5	*	4.3 ± 0.5	14.5 ± 0.6	17.5 ± 0.7	21.5 ± 3.8	55.5 ± 1.0	*
	(33.0-34.0)	(112.0-113.0)		(14.0-18.0)	(131.0-156.0)	(180.0-190.0)	(5.0-7.0)	(8.0-9.0)		(4.0-5.0)	(14.0-15.0)	(17.0-18.0)	(16.0-24.0)	(54.0-56.0)	
11	50.5 ± 1.0	118.0 ± 0.8	170+	36.0 ± 2.8	132.5 ± 3.4	152.5 ± 10.6	11.0 ± 1.4	10.0 ± 0.8	*	5.5 ± 0.6	13.8 ± 0.5	16.0 ± 1.4	31.0 ± 1.2	52.5 ± 1.0	*
	(49.0-51.0)	(117.0-119.0)		(32.0-38.0)	(128.0-136.0)	(145.0-160.0)	(10.0-13.0)	(9.0-11.0)		(5.0-6.0)	(13.0-14.0)	(15.0-17.0)	(30.0-32.0)	(52.0-54.0)	
12	37.5 ± 1.0	118.8 ± 0.5	170+	16.5 ± 1.0	127.8 ± 1.7	148.0 ± 0.0	6.0 ± 0.8	9.0 ± 1.4	*	4.3 ± 0.5	14.3 ± 1.0	17.0 ± 0.0	19.5 ± 1.0	49.5 ± 5.7	*
	(37.0-39.0)	(118.0-119.0)		(16.0-18.0)	(126.0-130.0)		(5.0-7.0)	(8.0-11.0)		(4.0-5.0)	(13.0-15.0)		(18.0-20.0)	(46.0-58.0)	
13	40.0 ± 0.0	129.8 ± 0.5	170+	14.0 ± 0.0	134.3 ± 1.3	167.5 ± 3.5	7.5 ± 1.0	7.5 ± 0.6	*	4.0 ± 0.0	16.5 ± 0.6	20.5 ± 0.7	24.0 ± 2.8	49.0 ± 2.6	*
		(129.0-130.0)			(133.0-136.0)	(165.0-170.0)	(6.0-8.0)	(7.0-8.0)			(16.0-17.0)	(20.0-21.0)	(20.0-26.0)	(46.0-52.0)	
14	40.0 ± 0.0	110.0 ± 1.4	170+	53.5 ± 2.1	81.0 ± 4.2	95.0 ± 0.0	26.0 ± 4.2	15.5 ± 0.7	*	5.0 ± 0.0	12.5 ± 0.7	16.0 ± 0.0	63.0 ± 9.9	75.0 ± 1.4	*
		(109.0-111.0)		(52.0-55.0)	(78.0-84.0)		(23.0-29.0)	(15.0-16.0)			(12.0-13.0)		(56.0-70.0)	(74.0-76.0)	
15	33.3 ± 0.5	66.0 ± 2.5	170+	16.8 ± 1.0	83.8 ± 5.6	220.0 ± 14.1	9.5 ± 1.3	30.5 ± 5.1	*	4.3 ± 0.5	8.8 ± 0.5	23.0 ± 1.4	19.5 ± 3.4	108.0 ± 8.4	*
	(33.0-34.0)	(63.0-68.0)		(16.0-18.0)	(78.0-89.0)	(210.0-230.0)	(8.0-11.0)	(24.0-35.0)		(4.0-5.0)	(8.0-9.0)	(22.0-24.0)	(16.0-24.0)	(97.0-115.0)	
16	36.8 ± 0.5	96.5 ± 1.0	170+	19.5 ± 1.9	119.0 ± 5.6	195.0 ± 7.1	7.8 ± 1.5	11.3 ± 1.5	*	4.3 ± 0.5	15.3 ± 0.5	22.5 ± 0.7	25.0 ± 2.6	70.0 ± 6.3	*
	(36.0-37.0)	(96.0-98.0)		(18.0-22.0)	(112.0-124.0)	(190.0-200.0)	(6.0-9.0)	(10.0-13.0)		(4.0-5.0)	(15.0-16.0)	(22.0-23.0)	(22.0-28.0)	(64.0-78.0)	
17	34.8 ± 1.3	78.5 ± 1.0	170+	16.3 ± 1.0	78.3 ± 3.3	225.0 ± 7.1	10.3 ± 1.0	24.8 ± 2.2	*	4.5 ± 0.6	7.8 ± 0.5	21.5 ± 0.7	21.5 ± 3.8	55.5 ± 1.0	*
	(33.0-36.0)	(78.0-80.0)		(15.0-17.0)	(74.0-82.0)	(220.0-230.0)	(9.0-11.0)	(22.0-27.0)		(4.0-5.0)	(7.0-8.0)	(21.0-22.0)	(16.0-24.0)	(54.0-56.0)	
18	35.3 ± 0.5	79.0 ± 1.2	170+	16.5 ± 1.9	92.0 ± 3.3	167.5 ± 10.6	7.6 ± 0.5	16.5 ± 1.9	*	3.8 ± 0.5	8.8 ± 0.5	17.5 ± 2.1	24.5 ± 1.9	82.5 ± 1.9	*
	(35.0-36.0)	(78.0-80.0)		(14.0-18.0)	(88.0-96.0)	(160.0-175.0)	(7.0-8.0)	(14.0-18.0)		(3.0-4.0)	(8.0-9.0)	(16.0-19.0)	(22.0-26.0)	(80.0-84.0)	
AVG	43.3	121.5	170+	30.0	131.7	179.3	12.2	11.8	*	4.6	14.8	19.4	35.0	61.2	*
SD	7.9	28.0	*	13.0	31.2	33.7	5.0	6.3	*	0.5	3.5	2.7	14.4	15.1	*
MAX	56.8	160.3	*	53.5	173.8	225.0	26.0	30.5	*	5.5	18.8	23.0	63.0	108.0	*
MIN	33.3	66.0	*	14.0	78.3	95.0	6.0	7.3	*	3.8	7.8	14.5	19.5	44.5	*

and local selection by farmers using traditional agricultural practices over long period of time. Similar differentiation of photoresponse by geographical distribution and local selection by farmers were also reported in other plants such as rice (Oka, 1954; Wada, 1954) and foxtail millet (Takei and Sakamoto, 1987, 1989).

Perilla probably originated in China as suggested by Makino (1961), because the main area of its diversity is in a very ancient site in China (Zeven and de Wet 1982), and yet the history of its cultivation is very old in China (Li, 1969). AFLP analyses of *Perilla* crops from East Asia (Lee and Ohnishi, 2001a) also suggested China as its original birth place and Korea as a secondary center. Therefore, we can consider the possibility that early and intermediate types of cultivated var. *frutescens* might differentiate from late maturing type by diffusing to Korea and Japan and adapted to their relatively short day condition. Then the early and intermediate types may be selected for cultivation in high latitude or mountainous areas. Most accessions of early maturing type (KOR1, KOR6, JA1 and JA8) were found in southern part of Korea and northern part of Japan (latitude: 35-43°N). These areas are cool in summer and have short cultivation period, and thus the early maturing type may be the most suitable for cultivation there.

We observed seed sterility (about 90%, when tested in Kyoto) in early maturing accessions from Korea and Japan (Lee and Ohinishi, 2001b). They flowered in the middle of July to the middle of August when it was very hot (above 30°C). Thus, *Perilla* crop cannot be grown under hot temperature conditions. The southern China is so hot in summer that all the accessions of early or intermediate type cannot be grown there. Only the late maturing accessions which summer at the vegetative stage and flowers in cool fall was found in the southern China. The sowing time cannot be delayed so long since hot dry soil condition in summer is harmful to seedlings of *Perilla.* All the weedy accessions of var. *frutescens* were late maturing in the southern China, and might be considered as a naturally adapted form having been selected by farmers or environmental condition.

Yu (1974), and Cho *et al.* (1984) suggested that the *Perilla*

Table 4. Correlation coefficient between days to flowering and morphological characters studied.

Correlation	Short-day condition (Plot A)	Nature daylength condition (Plot B)
Between QN1 and QN2	r = 0.69	r = 0.89
Between QN1 and QN3	r = 0.65	r = 0.93
Between QN1 and QN4	r = 0.45	r = - 0.78
Between QN1 and QN5	r = 0.69	r = - 0.72

Table 5. The temperature variation of the flowering date of *Perilla* crop accessions.

Code No.	Accession No.	Plot A				Plot B			
		Flowering date†	Temperature (°C)‡			Flowering date	Temperature (°C)		
			Max.	Min.	Avg.		Max.	Min.	Avg.
1	CH1	July 13	33.7	25.7	29.7	October 25	21.0	19.5	20.3
2	CH2	July 13	33.7	25.7	29.7	October 23	20.7	18.0	19.4
3	CH5	July 14	31.0	23.1	27.1	October 23	20.7	18.0	19.4
4	CH7	July 4	34.0	23.3	28.7	October 14	22.9	14.9	18.9
5	CH8	July 1	32.5	23.1	27.8	October 7	25.7	14.7	20.2
6	KOR11	July 2	34.3	24.2	29.3	September 26	26.3	18.1	22.2
7	KOR40	July 8	28.9	22.6	25.8	October 3	26.5	19.3	22.9
8	KOR3	July 3	35.2	24.1	29.7	September 15	32.7	26.3	29.5
9	KOR7	June 27	25.6	22.2	23.9	September 19	29.9	17.2	23.6
10	JA2	June 21	27.7	23.1	25.4	September 7	32.4	22.2	27.3
11	JA3	July 8	28.9	22.6	25.8	September 13	32.5	23.5	28.0
12	JA4	June 25	28.8	22.2	25.5	September 14	31.4	24.8	28.4
13	JA5	June 7	25.6	22.2	23.9	September 25	28.2	17.2	22.7
14	KOR18	June 26	28.8	22.2	25.5	September 5	30.8	19.2	25.0
15	KOR1	June 21	27.7	23.1	25.4	July 22	36.6	26.3	31.5
16	KOR6	June 24	30.1	23.8	27.0	August 22	35.6	25.7	30.7
17	JA1	June 22	27.5	22.6	25.1	August 6	36.0	25.7	30.9
18	JA8	June 22	27.5	22.6	25.1	August 6	36.0	25.7	30.9

†Date of 50% flowering per accession.
‡The temperature was used of the data of meteorological observatory, which was measured at Kyoto in 2000.

crop could not flower under 16 hrs or longer light treatment. The present result is consistent with these studies. Thus, the daylength condition severely affects flowering habit of *Perilla* crop, and it is considered as one of the most important environmental factors for the cultivation of *Perilla* crop.

Table 4 showed correlation coefficient between days to flowering and the other four characters under the short-day and natural daylength treatments. Plant height and internode number responded in the same direction both in plots A and B. Whereas inflorescence length and floret number of early and late maturing types responded in the opposite direction in plots A and B (Tables 3, 4). Day length may decide flowering time, hence determines the duration of vegetative growth period. Hence, the characters closely related to vegetative growth period, plant height and internode number were positively correlated to the days to flowering.

On the other hand, inflorescence length and floret number were positively correlated to the short-day condition, but were negatively correlated to the natural daylength condition. Although more detailed investigation and study are required, this result may be interpreted by considering that these characters are correlated with temperature condition at flowering time. When most accessions of late maturing type flowered in plots A and B, the average temperature at the flowering date was higher in plot A (from July 1 to July 14) than in plot B (from September 26 to October 25) (Table 5). In contrast, when most accessions of early maturing type flowered in plots A and B, the average temperature at the flowering date was lower in plot A (from June 21 to June 24) than in plot B (from July 22 to August 22) (Table 5). Since the temperature affects the length of inflorescence, the higher the temperature at flowering, the longer the length of inflorescence. This finding is in agreement with our results. In this study, the effect of the temperature on flowering was not critically studied, but it definitely affects the growth rate of morphological characters. The effect of temperature on *Perilla* crop was studied by Yu (1974), and Cho *et al.* (1984). They suggested that under the same daylength condition, flowering of *Perilla* crop was accelerated in high growing temperature condition. They also noticed that both high and low temperature conditions were not able to induce flowering of those plants grown under 16 hours photoperiod.

Although all accessions of late maturing type showed longer inflorescence in plot A than in plot B, their floret numbers were fewer in plot A than in plot B. This result indicated that the number of florets is more plentiful in natural daylength condition than the short-day treatment. Thus, the cultivation of natural environmental condition is must suitable for a good harvest.

In this study, flowering habit may be considered as a useful key character for the study of geographical differentiation of cultivated var. *frutescens*. Flowering habit is the most important characters for landrace establishment, because it can be determined by agricultural practices of local farmers and natural environmental conditions. Geographical differentiation of cultivated var. *frutescens* in East Asia may be the result from the diffusion of cultivation of *Perilla* crops and local selection for flowering habit by farmers using traditional agricultural practices over long period of time.

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