Cultivar differences in flowering response of okra (*Abelmoschus esculentus*) in spring and autumn

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Abstract : Differences in flowering response of ten accessions and five cultivars were investigated in spring and autumn.

Flower buds of HE 006, HE 022, HE 045, HE 047, HE 047-1, 'Benny', 'Better Five', 'Clemson Spineless', 'Emerald' and 'Green Rocket' were initiated at the lower node from 2 to 6 in spring and from 8 to 11 in autumn and they appeared 0 to 11 days earlier in spring than in autumn, depending on the cultivars. Flower bud initiation of HE 015, HE 050 and HE 050-1 was early in 18 to 21 days after sowing (DAS) but the initiation of HE 025 and HE 035 was late in 32 to 48 DAS whether in spring or in autumn. The occurrence of anthesis and fruiting in all accessions and cultivars fluctuated in the different seasons.

Based on these results, two groups of flowering response to environmental conditions in spring and autumn were identified as sensitive and non-sensitive cultivars. Sensitive cultivars comprised of HE 006, HE 022, HE 045, HE 047, HE 047-1, 'Benny', 'Better Five', 'Clemson Spineless', 'Emerald' and 'Green Rocket'. Non-sensitive cultivars were divided into two sub-groups as early and late flowering. Early flowering composed of HE 015, HE 050 and HE 050-1 and late flowering consisted of HE 025 and HE 035.

(Accepted September 9, 2003)

Key words : early flowering, late flowering, non-sensitive cultivar, sensitive cultivar.

Introduction

Okra (*Abelmoschus esculentus*) is an important vegetable grown throughout the tropical, subtropical and temperate regions. It is originated in the tropical region of West Africa, South Asia and South East Asia (Düzyaman, 1997). According to our previous report (Rithichai et al., 2002), flowers of okra were formed at the axillary position. They were initiated successively from the node bearing the first flower up to the node next to shoot apex. The immature fruits reached marketable size within few days after anthesis. They were able to harvest continuously and were consumed as cooking, fried or fresh vegetable. The young fruits provided dietary fiber, protein and good source of vitamin C and calcium (Düzyaman, 1997; Jambhale and Nerkar, 1998).

Okra is a tropical crop. But it can be grown during warm and hot seasons in the temperate zones. Okra has been reported as a short-day plant (Arulrajah and Ormrod, 1973; Oyolu, 1977; Nwoke, 1980, 1985; Tenga and Ormrod, 1985; Wyatt, 1985). In Japan, day-length during warm seasons was quite different. Photoperiod lengthens gradually in spring season while it shortens in autumn season. An important purpose for okra field

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production in temperate zones is seasonal extension. Therefore, knowledge of the cultivar differences will enable farmer to establish the appropriate growing period or the suitable growing regions for cultivation.

The authors collected some okra cultivars from Japan and some accessions from Thailand in order to study physiological and ecological properties. In this report, the differences of flowering response of ten accessions and five cultivars from Thailand and Japan, respectively, were investigated in spring and autumn.

Materials and Methods

Ten accessions and five cultivars (Table 1) were investigated on the differences of flowering response in spring and autumn.

The germinated seeds were sown individually in 9 cm diameter pot on May 13, 2002. The growing media consisted of sterilized soil: sand: vermiculite: compost; 2: 1: 1: 1 by volume. Fifty plants of each accession and cultivar were grown in the glasshouse. After the emergence of the 5th or 6th unfolded leaf, 30 seedlings of each accession and cultivar were planted in the field with spacing 30 X 30 cm on June 11. Manure, lime and slow release fertilizer, IB-604, were applied on a planting bed 30 X 2 m. The application rate of IB-604 (N-P-K; 16-10-14) was 37.6 kg · 1,000 m^{-2}. The bed was mulched with mulching film. The lateral branches were pinched out when they were about 2 cm in length.

Days from sowing to the appearance of flower buds, anthesis and fruiting has determined when the number of plants bearing flower bud, anthesis and fruiting was over 50%. Fruiting was examined when the petals abscised and the fruit appeared after fertilization. The number of nodes bearing flower buds counted from the cotyledon node was recorded. Stem length from the cotyledon node to shoot apex and stem diameter at the middle position between cotyledon node and shoot apex were recorded at planting date, 2 and 4 weeks after planting. Maximum and minimum air temperatures in the field were recorded.

In autumn, the same ten accessions and five cultivars were used. The seeds were sown on August 2 and were planted in the field on August 26. Cultivation was done in the same way as spring. Flowering response and plant growth were measured in the same procedures as spring.

Table 1. Okra accessions, cultivars and their origin.

Accession	Cultivar	Source/Origin
HE 006		Ayutthaya, Central Thailand
HE 015		Uthaithani, Northern Thailand
HE 022		Ratchaburi, Western Thailand
HE 025		Thailand
HE 035		Lumpang, Northern Thailand
HE 045		Pitsanulok, Northern Thailand
HE 047	OK#5	Nakhonpathom, Central Thailand
HE 047-1[z]	OK#5	Nakhonpathom, Central Thailand
HE 050	Bel-2	Myanmar
HE 050-1[z]	Bel-2	Myanmar
	Benny	Takii Seed Co., Japan
	Better Five	Takii Seed Co., Japan
	Clemson Spineless	Takayama Seed Co., Japan
	Emerald	Marutane Seed Co., Japan
	Green Rocket	Takii Seed Co., Japan

[z] The segregated accession.

Results

The number of nodes bearing flower buds: Flower buds of HE 006, HE 022, HE 045, HE 047, HE 047-1, 'Benny', 'Better Five', 'Clemson Spineless', 'Emerald' and 'Green Rocket' occurred at the lower node in spring than in autumn (Table 2). For example, flower buds of HE 006 occurred at the 2.2 ± 0.4 node in spring. But it was at the 8.5 ± 1.2 node in autumn.

Flower buds of HE 015, HE 050 and HE 050-1 appeared at the similar lower node while that of HE 025 and HE 035 occurred at the similar higher node either in spring or in autumn. For instance, flower buds of HE 015 appeared at the 2.0 ± 0.0 and 3.2 ± 0.4 node in spring and autumn, respectively. While flower buds of HE 025 occurred at the 9.8 ± 3.5 node in spring and the 11.1 ± 0.3 node in autumn.

Days from sowing to the appearance of flower buds: Flower buds of HE 006, HE 047, HE 047-1, 'Benny', 'Better Five', 'Clemson Spineless', 'Emerald' and 'Green Rocket' occured earlier in spring than in autumn. For instance, flower buds of HE 006 appeared at 21 days in spring. But it was 33 days in autumn.

Table 2. Cultivar differences in the flowering and fruiting of ten accessions and five cultivars.

Cultivar	Spring				Autumn			
	Node[z]	Days from sowing to			Node	Days from sowing to		
		budding[y]	anthesis	fruiting[x]		budding	anthesis	fruiting
Sensitive cultivars								
HE 006	2.2 ± 0.4[w]	21	46	47	8.5 ± 1.2	33	60	61
HE 022	6.2 ± 2.0	34	60	61	10.0 ± 0.0	35	65	66
HE 045	6.6 ± 2.5	34	63	64	11.7 ± 0.5	34	62	63
HE 047	4.6 ± 2.2	23	53	54	10.8 ± 0.4	34	62	63
HE 047-1	3.4 ± 2.2	23	49	50	11.2 ± 0.5	34	61	62
Benny	2.1 ± 0.3	19	42	43	9.8 ± 0.4	34	60	61
Better Five	2.1 ± 0.3	21	40	41	7.9 ± 1.3	30	53	54
Clemson Spineless	3.2 ± 0.9	22	55	56	9.5 ± 0.5	32	57	58
Emerald	3.3 ± 1.4	23	47	48	9.7 ± 0.5	33	57	58
Green Rocket	2.0 ± 0.0	21	40	41	9.4 ± 0.8	30	53	54
Non-sensitive cultivars								
Early flowering								
HE 015	2.0 ± 0.0	21	42	43	3.2 ± 0.4	21	42	43
HE 050	2.2 ± 0.4	18	40	41	4.0 ± 1.3	17	39	40
HE 050-1	2.0 ± 0.0	18	38	39	3.5 ± 0.8	16	37	38
Late flowering								
HE 025	9.8 ± 3.5	48	82	83	11.1 ± 0.3	36	66	67
HE 035	6.7 ± 1.2	32	83	84	9.5 ± 0.7	34	64	65

z The number of nodes bearing flower buds.
y The appearance of flower buds.
x The appearance of fruits after fertilization.
w Mean ± S.D.

Flower buds of HE 015, HE 050 and HE 050-1 occurred early at the similar time in spring and autumn. For example, flower buds of HE 015 appeared at 21 days in spring and autumn. While flower buds of HE 022, HE 035, HE 045 occurred late at the similar time in spring and autumn. For instance, flower buds of HE 022 occurred at 34 and 35 days in spring and autumn, respectively.

Flower buds of HE 025 occurred earlier in autumn than in spring. It appeared at 36 days in autumn and 48 days in spring.

Days from sowing to anthesis: Flowers of HE 006, HE 022, HE 047, HE 047-1, ‘Benny’, ‘Better Five’, ‘Emerald’ and ‘Green Rocket’ opened earlier in spring than in autumn. For example, flowers of HE 006 opened at 46 days in spring. But it was 60 days in autumn.

Flowers of HE 015, HE 050, HE 050-1 opened early at the similar time in spring and autumn. For instance, flowers of HE 015 opened at 42 days in spring and autumn. In contrast to HE 045 and ‘Clemson Spineless’, flowers opened late at the similar time in spring and autumn. For example, flowers of HE 045 opened at 63 and 62 days in spring and autumn, respectively.

Flowers of HE 025 and HE 035 opened earlier in autumn than in spring. Flowers of HE 025 opened at 66 days in autumn. But it was 82 days in spring. The same tendency in the time to anthesis occurred in HE 035 as HE 025.

Days from sowing to fruiting: Flowers developed into fruiting stage within one day after anthesis in all accessions and cultivars in spring and autumn. All accessions and cultivars showed the same tendency in times to fruiting as times to anthesis.

Plant growth: Plants of all accessions and cultivars grew gradually during 2 weeks after planting (data

Table 3. Cultivar differences in the stem length of ten accessions and five cultivars at 4 weeks after planting.

Cultivar	Stem length (cm)	
	Spring	Autumn
Sensitive cultivars		
HE 006	28.3 ± 1.9[z]	42.8 ± 3.8
HE 022	37.0 ± 1.8	50.5 ± 5.0
HE 045	54.5 ± 2.9	68.2 ± 3.7
HE 047	41.2 ± 2.6	58.7 ± 2.9
HE 047-1	43.7 ± 2.4	54.2 ± 5.3
Benny	71.7 ± 2.9	93.8 ± 4.7
Better Five	38.6 ± 0.9	54.8 ± 3.2
Clemson Spineless	46.8 ± 1.3	65.7 ± 5.7
Emerald	38.5 ± 1.2	58.5 ± 2.9
Green Rocket	38.3 ± 2.3	62.1 ± 5.0
Non-sensitive cultivars		
Early flowering		
HE 015	38.7 ± 2.2	60.7 ± 6.0
HE 050	66.5 ± 2.6	91.9 ± 6.0
HE 050-1	66.0 ± 3.6	97.9 ± 3.3
Late flowering		
HE 025	63.6 ± 2.5	82.8 ± 3.1
HE 035	65.8 ± 3.0	83.5 ± 2.3

z Mean ± S.D.

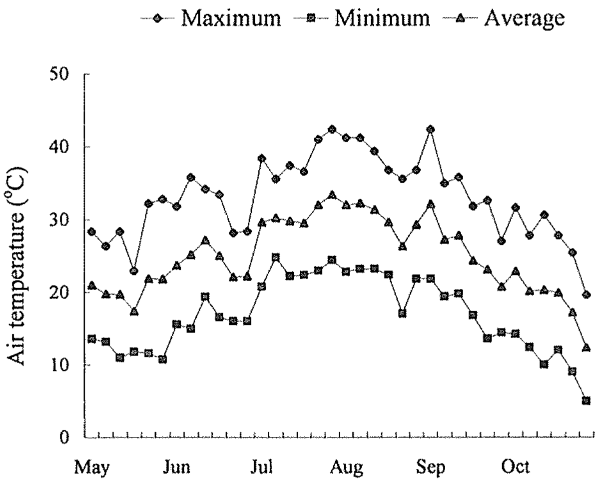

Fig. 1. Changes of air temperatures in the field during May to October 2002. Each data represented the mean of 5 days.

not shown). Thereafter, plant growth increased dramatically as indicated by stem length at 4 weeks after planting either in spring or in autumn (Table 3). Stem length differed from 28.3 ± 1.9 cm in HE 006 to 71.7 ± 2.9 cm in 'Benny' in spring. While it varied from 42.8 ± 3.8 cm in HE 006 to 97.9 ± 3.3 cm in HE 050-1 in autumn.

Air temperature: In spring, average air temperature was about 20°C at the beginning of experiment and it increased gradually nearly 30°C at the end of experiment (Fig. 1). On the other hand, average air temperature was about 30°C at the beginning of experiment and it decreased gradually nearly 20°C at the end of experiment in autumn.

Discussion

Flowering of ten accessions and five cultivars differed in spring and autumn seasons. The earliness or lateness of flowering was capable to measure by the amount of vegetative growth as the number of nodes preceding the first flower and the length of time to the appearance of flower buds or anthesis. For flowering measurement, the number of nodes bearing flower buds was the most reliable parameter while the length of time to the appearance of flower buds or anthesis was the simplest parameter (Lang, 1965; Schwabe, 1971).

Two groups of flowering response to environmental conditions in spring and autumn were identified. In the first group, flower buds of HE 006 were initiated at the lower node and flower buds occurred earlier in spring when photoperiod lengthened from 14 hr to 14.30 hr and average air temperature increased gradually from 20°C to 30°C. In contrast, they were initiated at the higher node and the appearance of flower buds delayed in autumn when photoperiod shortened from 13.45 hr to 11.30 hr and average air temperature declined gradually from 30°C to 20°C. HE 022, HE 045, HE 047, HE 047-1, 'Benny', 'Better Five', 'Clemson

Spineless', 'Emerald' and 'Green Rocket' exhibited the same tendency in flower bud initiation as HE 006. These indicated that flowering of those accessions and cultivars were sensitive to environmental conditions in spring and autumn. Okra was reported as a short-day plant (Arulrajah and Ormrod, 1973; Oyolu, 1977; Nwoke, 1980, 1985; Tenga and Ormrod, 1985; Wyatt, 1985). In this study, flowering of HE 006, HE 022, HE 045, HE 047, HE 047-1, 'Benny', 'Better Five', 'Clemson Spineless', 'Emerald' and 'Green Rocket' occurred earlier in long-day conditions with increasing temperature in spring. Hence, flower bud initiation of these accessions and cultivars appeared to be controlled primarily by temperature rather than photoperiod. Based on the changes of air temperature, low air temperature at the beginning of experiment may promote flower bud initiation in these cultivars and accessions. Arulrajah and Ormrod (1973) described that flower bud initiation of okra was promoted at 25/20°C. In contrast, it was prevented at high temperatures of 30/25°C and 35/30°C. Similarly, cool temperature of 30/20°C induced flower initiation at the lower node when compared with 36/27°C (Tenga and Ormrod, 1985).

In the second group, flower buds of HE 015, HE 050 and HE 050-1 were initiated at the similar lower node and flower buds occurred at the similar early time in spring and autumn. However, the number of nodes bearing flower buds of these accessions was little lower in spring than in autumn. These implied that environmental factors in spring and autumn did not affect flower bud initiation but environmental factors in spring were more favorable conditions for flowering of these accessions. These results were consistent with our previous observations that flower bud initiation of HE 015 and HE 050 did not affect by different photoperiods of 10 or 16 hr (Rithichai et al., 2003).

Flower bud initiation was late in HE 025 and HE 035 whether in spring or in autumn. These implied that HE 025 and HE 035 were not sensitive to environmental conditions in spring and autumn but they might require short-day conditions to promote flowering. The day-length experiment of Rithichai et al. (2003) confirmed that flower bud initiation of HE 025 and HE 035 was promoted in short photoperiod of 10 hr but it was prevented in long photoperiod of 16 hr. Moreover, Nwoke (1980) reported that both early and late cultivars of okra were short-day plant. The early okra cultivars required 6 short-day cycles (10 hr of short photoperiod), while the late okra cultivars required 14 short-day cycles for the induction of flowering.

Flowers of all accessions and cultivars required 20 –30 days to develop from the visible flower buds to anthesis in spring and autumn except HE 025, HE 035 and 'Clemson Spineless'. HE 025, HE 035 and 'Clemson Spineless'required longer time as 34, 51 and 33 days, respectively, from the appearance of flower buds developed into anthesis in spring. It was noticeable that the first flower of HE 025, HE 035 and 'Clemson Spineless' ceased to develop and abscised before anthesis. The higher node of the first opening flower resulted in the longer time to anthesis in these accessions and cultivar. These indicated that flower development of HE 025, HE 035 and 'Clemson Spineless' were strongly influenced by long-day conditions and increasing temperature in spring. Arulrajah and Ormrod (1973) noted that the combination of high temperatures of 30/25°C and 35/30°C and long photoperiod of 15 hr retarded or prevented flower expansion. Similarly, Nwoke (1980) reported that okra needed more than 20 short-day cycles for flower opening.

Okra plants of all accessions and cultivars grew faster in autumn than in spring as indicated by stem length at 4 weeks after planting. High temperature in the beginning of experiment in autumn resulted in the promotion of plant growth. Sionit et al. (1981) reported that okra was very sensitive to low temperature. Okra plants died after 17 days after emergence at 17/11°C while they reached maturity at 26/26°C. Similarly, Tenga and Ormrod (1985) noted that high night temperature of 36/27°C produced taller plants than cool night temperature of 36/20°C.

Based on these results, HE 006, HE 022, HE 045, HE 047, HE 047-1, 'Benny', 'Better Five', 'Clemson Spineless', 'Emerald' and 'Green Rocket' were sensitive to environmental conditions in spring and autumn. Flowering of these accessions and cultivars was early in spring but it was late in autumn. On the other hand, HE 015, HE 025, HE 035, HE 050 and HE 050-1 did not sensitive to environmental conditions. Flowering of HE 015, HE 050 and HE 050-1 was early while flowering of HE 025 and HE 035 was late in spring and autumn.

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春季並び秋季におけるオクラ（*Abelmoschus esculentus*）花成反応の品種間差異

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摘要：オクラの10系統と5品種を供試して，春季と秋季において花成反応の品種間差異を調査した。系統HE006，HE022，HE045，HE047，HE047-1と‘Benny’，‘Better Five’，‘Clemson Spineless’，‘Emerald’，‘Green Rocket’の花芽は春季では2～6の低節位に，秋季には8～11節の低節位に形成された。秋季に比べて春季で品種間に差はあるが，出雷は0～11日早くおこった。季節に関わらず，HE015，HE050，HE050-1の花芽は播種後18～21日と早く形成されたが，HE025，HE035では32日～48日と遅く形成された。すべての系統と品種について，開花と結実時期は季節によって変動した。

春季と秋季の環境条件に対する花成反応から，敏感な品種とそうでない品種に分けられた。敏感な品種にはHE006，HE022，HE045，HE047，HE047-1，‘Benny’，‘Better Five’，‘Clemson Spineless’，‘Emerald’と‘Green Rocket’があった。敏感でない品種は2群に分けられ，花芽分化の早いのはHE015，HE050，HE050-1であり，遅いのはHE025，HE035であった。