

Morphological properties of flower and fruit in okra (*Abelmoschus esculentus*)

PANUMART RITHICHAI¹⁾, YUKIHIRO FUJIME²⁾, SUTEVEE SUKPRAKARN³⁾,
SATOSHI TERABAYASHI²⁾ and SHUICHI DATE²⁾

Abstract : Twenty okra cultivars from Japan and ten okra accessions from Thailand were cultivated to compare the morphological properties of flowers and fruits.

Flower organs of all cultivars and accessions were quite similar in appearance at anthesis. The slender fruits with pentagon or round shaped were observed. All cultivars and accessions in this study belonged to *Abelmoschus esculentus*.

Twenty cultivars and ten accessions were divided into 3 clusters. Cluster I consisted of 'Benny', 'Better Five', 'Blue Sky', 'Early Five', 'Emerald', 'Green Etude', 'Green Five', 'Green Rocket', 'Green Star', 'Gulliver', 'Holiday', 'Miyako Gokaku', 'Natsu no Megumi', 'Peak Five', 'Pentagon', 'Star Debut', 'Star Light', 'Suisei Gokaku', HE 015, HE 045, HE 047, HE 047-1 and HE 050-1. Cluster II was composed of 'Blue Sky Z', 'Clemson Spineless', HE 006 and HE 050. Cluster III was comprised of HE 022, HE 025 and HE 035.

(Accepted September 10, 2004)

Key words : cluster analysis, correlation.

Introduction

Okra belongs to the family Malvaceae. Cultivated okra and related wild species were originally grouped in the genus *Hibiscus*, section *Abelmoschus*. Based on the calyx character, the fusion among calyx, petal and stamen at the basal part and the abscission of these floral organs after anthesis, *Abelmoschus* was then distinguished and was recognized as the new genus (Van Borssum Waalkes, 1966; Bates, 1968). The origin of okra is rather obscure (Yamaguchi, 1983). However, Van Borssum Waalkes (1966), Siemonsma (1982), Bisht et al. (1995) and Düzyaman (1997) reported that the centers of diversity of *Abelmoschus* were West Africa, South Asia and Southeast Asia. The genus *Abelmoschus* is comprised of nine species (Düzyaman, 1997). Only *A. esculentus* and *A. caillei* (the second edible okra species) are cultivated as fresh fruits (Hamon and Hamon, 1991; Düzyaman, 1997).

The appearances of fruits such as shape, size and color are important characters for horticultural products. The variation of flower and fruit characters among these cultivars and accessions will be useful for further study not only for horticultural crop improvement but also for year-round culture of okra.

In this study, morphological properties of flowers and fruits in twenty cultivars from Japan and ten accessions from Thailand were investigated.

¹⁾ Department of Agricultural Technology, Faculty of Science and Technology, Thammasat University, Pathumthani 12121, Thailand.

²⁾ Graduate School of Agriculture, Kyoto Prefectural University, Sakyo, Kyoto 606-8522.

³⁾ Tropical Vegetable Research Center, Kasetsart University, Nakhonpathom 73140, Thailand.

Materials and Methods

Seeds of ten accessions (Table 1) were obtained from Tropical Vegetable Research Center, Kasetsart University, Thailand. The seeds were multiplied at the experimental field of Kyoto Prefectural University during May to August 2001. The mature flower buds were covered by paper bags before anthesis in order to prevent cross-pollination. Seeds of twenty commercial cultivars were gathered in Japan.

Seeds of twenty cultivars from Japan and ten accessions from Thailand were sown individually in 9 cm plastic pots on May 2002. Twenty-four plants of each cultivar and accession were cultivated in the glasshouse. The growing media consisted of sterilized soil: sand: vermiculite: compost; 2: 1: 1: 1 by volume. After the emergence of the 5th or 6th unfolded leaf, 12 seedlings of each cultivar and accession were planted in the field on June in spacing 30×30 cm. Manure, lime and slow release fertilizer, IB-604 (N-P-K; 16-10-14), were applied on a planting bed of 30×2 m. The application rate of IB-604 was 37.6 kg · 1,000 m⁻². The bed was covered with mulching film.

Twelve flowers were sampled at anthesis. The number, length and width of bracteoles, petal number, locule number and pedicel length were measured. Fruit shape, color, length, diameter, weight, pedicel length, locule number and seed number were recorded, using 12 fruits 6 days after anthesis (DAA). The ratio of fruit length to fruit diameter was calculated.

Correlation coefficient was calculated from the mean values of flower and fruit characters of twenty cultivars and ten accessions and a cluster analysis was examined using the statistic software, SPSS 10.0 for Windows. A dendrogram was constructed by Ward's method and the matrix was calculated using squared euclidean distance.

Table 1. Okra cultivars and accessions gathered from different sources.

| Accession | Cultivar | Source |
|-----------------------|-------------------|--------------------------------|
| | Benny | Takii Seed Co., Japan |
| | Better Five | Takii Seed Co., Japan |
| | Blue Sky | Kyowa Seed Co., Japan |
| | Blue Sky Z | Kyowa Seed Co., Japan |
| | Clemson Spineless | Takayama Seed Co., Japan |
| | Early Five | Takii Seed Co., Japan |
| | Emerald | Marutane Seed Co., Japan |
| | Green Etude | Takii Seed Co., Japan |
| | Green Five | Takayama Seed Co., Japan |
| | Green Rocket | Takii Seed Co., Japan |
| | Green Star | Marutane Seed Co., Japan |
| | Gulliver | Kaneko Seed Co., Japan |
| | Holiday | Kaneko Seed Co., Japan |
| | Miyako Kogaku | Marutane Seed Co., Japan |
| | Natsu no Megumi | Watanabe Noji Co., Japan |
| | Peak Five | Sakata Seed Co., Japan |
| | Pentagon | Marutane Seed Co., Japan |
| | Star Debut | Musashino Seed Co., Japan |
| | Star Light | Musashino Seed Co., Japan |
| | Suisei Gokaku | Watanabe Noji Co., Japan |
| HE 006 | | Ayutthaya, Central Thailand |
| HE 015 | | Uthathani, 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 ² | OK#5 | Nakhonpathom, Central Thailand |
| HE 050 | Bel-2 | Myanmar |
| HE 050-1 ² | Bel-2 | Myanmar |

² The segregated accession.

Table 2. Flower characters of twenty cultivars and ten accessions.

| Cultivar | Bracteole | | | Petal no. | Locule no. | Pedicel length(cm) |
|-------------------|------------------------|-------------|------------|-----------|------------|--------------------|
| | No. | Length (mm) | Width (mm) | | | |
| Benny | 8.7 ± 1.1 ² | 14.7 ± 0.9 | 1.4 ± 0.1 | 5.0 ± 0.0 | 6.0 ± 0.9 | 1.8 ± 0.2 |
| Better Five | 10.7 ± 1.3 | 15.6 ± 0.8 | 1.2 ± 0.1 | 5.0 ± 0.0 | 5.0 ± 0.0 | 1.6 ± 0.2 |
| Blue Sky | 10.2 ± 1.5 | 15.6 ± 2.0 | 1.3 ± 0.2 | 5.0 ± 0.0 | 5.0 ± 0.0 | 2.2 ± 0.6 |
| Blue Sky Z | 10.3 ± 1.1 | 15.4 ± 2.2 | 1.3 ± 0.3 | 5.0 ± 0.0 | 5.0 ± 0.0 | 2.0 ± 0.4 |
| Clemson Spineless | 11.1 ± 0.9 | 15.0 ± 1.4 | 1.4 ± 0.2 | 5.0 ± 0.0 | 7.2 ± 1.3 | 3.8 ± 0.4 |
| Early Five | 9.8 ± 1.0 | 14.2 ± 1.3 | 1.3 ± 0.2 | 5.0 ± 0.0 | 5.0 ± 0.0 | 1.9 ± 0.3 |
| Emerald | 11.7 ± 1.4 | 16.8 ± 1.1 | 1.3 ± 0.2 | 5.0 ± 0.0 | 5.2 ± 0.4 | 2.9 ± 0.4 |
| Green Etude | 10.2 ± 1.1 | 16.9 ± 1.7 | 1.4 ± 0.2 | 5.0 ± 0.0 | 5.0 ± 0.0 | 2.4 ± 0.4 |
| Green Five | 9.2 ± 0.7 | 15.3 ± 0.6 | 1.6 ± 0.2 | 5.0 ± 0.0 | 5.2 ± 0.4 | 3.0 ± 0.6 |
| Green Rocket | 10.2 ± 1.4 | 15.8 ± 1.4 | 1.2 ± 0.2 | 5.0 ± 0.0 | 5.0 ± 0.0 | 1.5 ± 0.2 |
| Green Star | 9.6 ± 1.2 | 19.2 ± 1.3 | 1.3 ± 0.1 | 5.0 ± 0.0 | 5.1 ± 0.3 | 2.8 ± 0.5 |
| Gulliver | 8.6 ± 0.9 | 16.7 ± 1.9 | 1.7 ± 0.3 | 5.0 ± 0.0 | 5.0 ± 0.0 | 2.6 ± 0.9 |
| Holiday | 9.5 ± 1.2 | 18.3 ± 2.2 | 1.4 ± 0.2 | 5.0 ± 0.0 | 5.2 ± 0.4 | 2.6 ± 0.9 |
| Miyako Gokaku | 10.4 ± 1.6 | 18.5 ± 1.9 | 1.4 ± 0.3 | 5.0 ± 0.0 | 5.0 ± 0.0 | 2.5 ± 0.7 |
| Natsu no Megumi | 9.7 ± 1.5 | 16.9 ± 2.4 | 1.3 ± 0.3 | 5.0 ± 0.0 | 5.1 ± 0.3 | 2.9 ± 0.9 |
| Peak Five | 9.2 ± 1.2 | 17.2 ± 2.1 | 1.4 ± 0.2 | 5.0 ± 0.0 | 5.0 ± 0.0 | 2.5 ± 0.8 |
| Pentagon | 8.5 ± 1.2 | 17.2 ± 0.9 | 1.7 ± 0.2 | 5.0 ± 0.0 | 5.0 ± 0.0 | 3.9 ± 0.7 |
| Star Debut | 8.3 ± 0.6 | 17.0 ± 0.9 | 1.8 ± 0.2 | 5.0 ± 0.0 | 5.0 ± 0.0 | 3.8 ± 0.5 |
| Star Light | 9.2 ± 1.1 | 18.2 ± 2.1 | 1.5 ± 0.2 | 5.0 ± 0.0 | 5.0 ± 0.0 | 3.1 ± 0.9 |
| Suisei Gokaku | 9.8 ± 1.2 | 19.6 ± 1.6 | 1.4 ± 0.2 | 5.0 ± 0.0 | 5.0 ± 0.0 | 2.3 ± 0.4 |
| HE 006 | 11.0 ± 1.3 | 15.5 ± 1.0 | 1.2 ± 0.1 | 5.0 ± 0.0 | 5.9 ± 0.7 | 1.8 ± 0.2 |
| HE 015 | 9.8 ± 1.1 | 15.3 ± 0.6 | 1.3 ± 0.2 | 5.0 ± 0.0 | 6.5 ± 0.8 | 1.8 ± 0.2 |
| HE 022 | 9.6 ± 1.2 | 17.2 ± 1.4 | 1.5 ± 0.2 | 5.9 ± 0.9 | 7.7 ± 1.1 | 4.5 ± 0.6 |
| HE 025 | 9.0 ± 0.9 | 17.7 ± 1.1 | 1.7 ± 0.3 | 5.0 ± 0.0 | 6.6 ± 0.9 | 1.8 ± 0.3 |
| HE 035 | 9.2 ± 1.2 | 18.7 ± 1.1 | 1.8 ± 0.2 | 6.2 ± 1.1 | 7.4 ± 0.7 | 2.3 ± 0.4 |
| HE 045 | 10.8 ± 0.8 | 17.9 ± 1.6 | 1.5 ± 0.2 | 5.0 ± 0.0 | 5.1 ± 0.3 | 4.5 ± 0.8 |
| HE 047 | 10.1 ± 1.4 | 17.3 ± 3.4 | 1.5 ± 0.2 | 5.0 ± 0.0 | 5.2 ± 0.4 | 2.9 ± 1.0 |
| HE 047-1 | 9.8 ± 0.6 | 16.4 ± 1.6 | 1.3 ± 0.2 | 5.0 ± 0.0 | 5.0 ± 0.0 | 2.8 ± 0.5 |
| HE 050 | 10.4 ± 1.0 | 20.1 ± 1.2 | 1.3 ± 0.2 | 5.0 ± 0.0 | 5.2 ± 0.4 | 1.5 ± 0.4 |
| HE 050-1 | 10.8 ± 0.9 | 12.6 ± 2.0 | 1.1 ± 0.1 | 5.0 ± 0.0 | 5.9 ± 0.5 | 1.2 ± 0.2 |

² Mean ± SD.

(At anthesis)

Results

Flower characters

Epicalyx: The number of bracteoles differed in the range of 8.3 ± 0.6 in 'Star Debut' to 11.7 ± 1.4 in 'Emerald' (Table 2). The individual bracteole of epicalyx in all cultivars and accessions was linear in shape. Epicalyx was green in color except 'Benny' that was red in color. The longest bracteole was observed in HE 050 (20.1 ± 1.2 mm) and shortest in HE 050-1 (12.6 ± 2.0 mm). The widest bracteole was observed in HE 035 (1.8 ± 0.2 mm) and narrowest in HE 050-1 (1.1 ± 0.1 mm).

Petal: Five petals were observed in all cultivars and accessions except HE 022 and HE 035. The number of petals was 6.2 ± 1.1 in HE 035 and 5.9 ± 0.9 in HE 022. The petals of all cultivars and accessions were yellow in color with large dark reddish-purple spot at the base. They were positioned overlapping each other. The direction of rotation was shown either left-handed or right-handed within each cultivar or accession.

The number of loculi: Five loculi were observed in all accessions and cultivars except 'Clemson Spineless', HE 015, HE 022 and HE 035. The number of loculi was 6.5 ± 0.8 in HE 015, 6.9 ± 0.9 in HE 025, 7.2 ± 1.3 in 'Clemson Spineless', 7.4 ± 0.7 in HE 035 and 7.7 ± 1.1 in HE 022.

Pedicle length: Pedicle length differed in the range of 1.2 ± 0.2 cm in HE 050-1 to 4.5 ± 0.6 cm in HE 022. The length of pedicle longer than 4 cm was observed in HE 022 and HE 045.

Fruit characters

Okra fruits of all cultivars and accessions were long and thin (Fig. 1). The slender fruits with five ridges commonly occurred in all cultivars except 'Benny' and 'Clemson Spineless' that showed fruits with ridges more than five. Only HE 047, HE 047-1, HE 050 and HE 050-1 exhibited fruits with five ridges. On the other hand, slender fruits with ridgeless were observed in 'Emerald', HE 025 and HE 045. Fruit of all cultivars and accessions was green in color except 'Benny' that was red in color (Table 3). The variation among the green fruits; e.g., yellowish-green, light green, green and dark green fruits, was observed.

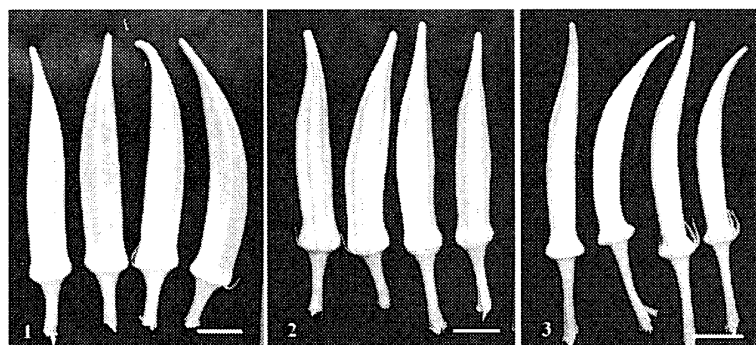


Fig. 1. Okra fruits. 1: 'Early Five' fruits with five ridges or pentagon. 2: 'Clemson Spineless' fruits with ridges more than five or round shaped. 3: HE 045 fruits with ridgeless or round shaped. Bar represented 3 cm.

Fruit length: Fruit length differed in a range of 7.4 ± 0.8 cm in HE 022 to 17.0 ± 2.1 cm in HE 050. Fruit length shorter than 10 cm was observed in 'Green Etude', HE 022 and HE 035. But it was longer than 13 cm in 'Benny', 'Green Rocket', 'Emerald', HE 015, HE 025, HE 050 and HE 050-1. The other cultivars and accessions showed fruit length between 10 to 13 cm.

Fruit diameter: Fruit diameter varied from 1.6 ± 0.1 cm in 'Emerald' to 2.4 ± 0.2 cm in 'Better Five'.
The ratio of fruit length to fruit diameter: The ratio of fruit length to fruit diameter differed in a range of 3.8 ± 0.4 in HE 022 to 9.2 ± 0.5 in 'Emerald' and 9.2 ± 1.1 in HE 050. 'Better Five', 'Green Etude', HE 022, HE 035 showed the ratio of fruit length to fruit diameter less than five. But it was more than six in 'Benny', 'Emerald', HE 045, HE 050 and HE 050-1.

Fruit weight: Fruit weight differed from 13.6 ± 2.6 g in HE 022 to 29.9 ± 11.6 g in HE 025. Fruit weight less than 15 g was observed in 'Green Etude' and HE 022. Only fruit weight of HE 025 was more than 25 g. Fruit weight of 'Blue Sky', 'Clemson Spineless', 'Early Five', 'Pentagon' and HE 015 was between 21-25 g. Fruit weight of others cultivars or accessions was between 15-20 g.

Pedicle length: Pedicle length differed in a range of 1.6 ± 0.3 cm in 'Green Rocket' to 4.1 ± 0.4 cm in HE 022. Pedicle length longer than 3 cm was observed in 'Clemson Spineless', 'Pentagon', 'Star Debut', HE 022, HE 025, HE 035 and HE 045. It was shorter than 2 cm in 'Better Five', 'Green Rocket', 'Suisei Gokaku', HE 015, HE 050 and HE 050-1.

Table 3. Fruit characters of twenty cultivars and ten accessions.

| Cultivar | Fruit | | | | Pedicel length (cm) | Fruit ² color | Locule no. | Seed no./ fruit |
|-------------------|-------------------------|---------------|-----------------|-------------|---------------------|--------------------------|------------|-----------------|
| | Length (cm) | Diameter (cm) | length/diameter | Weight (g) | | | | |
| Benny | 13.3 ± 1.4 ^y | 1.9 ± 0.1 | 7.1 ± 0.4 | 19.4 ± 4.0 | 2.4 ± 0.4 | 5 | 6.2 ± 0.8 | 70.6 ± 8.1 |
| Better Five | 11.5 ± 1.1 | 2.4 ± 0.2 | 4.7 ± 0.4 | 19.5 ± 3.1 | 1.9 ± 0.2 | 3 | 5.1 ± 0.3 | 64.1 ± 3.3 |
| Blue Sky | 12.7 ± 1.2 | 2.3 ± 0.2 | 5.6 ± 0.5 | 21.2 ± 2.7 | 2.3 ± 0.2 | 3 | 5.1 ± 0.3 | 61.5 ± 5.6 |
| Blue Sky Z | 12.2 ± 1.3 | 2.2 ± 0.2 | 5.5 ± 0.3 | 20.2 ± 5.1 | 2.2 ± 0.4 | 4 | 5.1 ± 0.3 | 62.1 ± 11.0 |
| Clemson Spineless | 12.6 ± 0.8 | 2.4 ± 0.2 | 5.3 ± 0.4 | 24.5 ± 3.9 | 3.5 ± 0.6 | 2 | 6.9 ± 1.3 | 67.8 ± 6.9 |
| Early Five | 13.0 ± 0.8 | 2.4 ± 0.1 | 5.4 ± 0.4 | 22.4 ± 2.0 | 2.2 ± 0.2 | 4 | 5.0 ± 0.0 | 65.7 ± 6.7 |
| Emerald | 14.3 ± 1.5 | 1.6 ± 0.1 | 9.2 ± 0.5 | 16.3 ± 3.7 | 2.8 ± 0.3 | 3 | 5.0 ± 0.0 | 50.5 ± 5.0 |
| Green Etude | 9.7 ± 0.8 | 2.2 ± 0.1 | 4.4 ± 0.3 | 14.6 ± 2.0 | 2.0 ± 0.3 | 4 | 5.0 ± 0.0 | 60.7 ± 6.8 |
| Green Five | 10.7 ± 0.9 | 2.1 ± 0.1 | 5.1 ± 0.2 | 16.7 ± 2.5 | 2.5 ± 0.5 | 4 | 5.0 ± 0.0 | 62.9 ± 7.1 |
| Green Rocket | 13.6 ± 0.7 | 2.3 ± 0.2 | 5.9 ± 0.3 | 20.4 ± 3.1 | 1.6 ± 0.3 | 3 | 5.0 ± 0.0 | 47.7 ± 5.0 |
| Green Star | 10.9 ± 1.4 | 2.1 ± 0.2 | 5.3 ± 0.5 | 15.5 ± 3.5 | 2.1 ± 0.4 | 3 | 5.2 ± 0.4 | 58.0 ± 12.4 |
| Gulliver | 11.1 ± 1.9 | 2.0 ± 0.2 | 5.5 ± 0.5 | 17.4 ± 5.9 | 2.2 ± 0.4 | 4 | 5.0 ± 0.0 | 71.2 ± 8.6 |
| Holiday | 12.4 ± 1.5 | 2.2 ± 0.2 | 5.6 ± 0.6 | 20.8 ± 5.0 | 2.4 ± 0.4 | 3 | 5.1 ± 0.3 | 66.2 ± 7.1 |
| Miyako Gokaku | 11.4 ± 1.0 | 2.1 ± 0.1 | 5.4 ± 0.5 | 16.7 ± 1.7 | 2.3 ± 0.2 | 3 | 5.1 ± 0.3 | 61.2 ± 7.9 |
| Natsu no Megumi | 10.7 ± 1.3 | 1.9 ± 0.1 | 5.5 ± 0.5 | 15.2 ± 3.0 | 2.4 ± 0.4 | 3 | 5.0 ± 0.0 | 67.7 ± 3.2 |
| Peak Five | 11.2 ± 1.0 | 2.0 ± 0.2 | 5.6 ± 0.4 | 16.5 ± 2.3 | 2.2 ± 0.3 | 3 | 5.1 ± 0.3 | 67.5 ± 6.6 |
| Pentagon | 12.9 ± 1.7 | 2.2 ± 0.2 | 5.9 ± 0.2 | 23.2 ± 6.1 | 3.6 ± 0.6 | 4 | 5.0 ± 0.0 | 68.6 ± 4.7 |
| Star Debut | 10.5 ± 1.9 | 2.0 ± 0.3 | 5.4 ± 0.6 | 16.6 ± 5.1 | 3.1 ± 0.3 | 4 | 5.0 ± 0.0 | 61.2 ± 7.1 |
| Star Light | 10.9 ± 1.2 | 2.0 ± 0.2 | 5.5 ± 0.4 | 15.7 ± 2.8 | 2.2 ± 0.4 | 4 | 5.0 ± 0.0 | 65.5 ± 5.0 |
| Suiser Gokaku | 10.9 ± 1.1 | 2.1 ± 0.1 | 5.2 ± 0.6 | 16.0 ± 2.2 | 1.9 ± 0.2 | 3 | 5.1 ± 0.3 | 60.0 ± 5.6 |
| HE 006 | 11.9 ± 1.1 | 2.2 ± 0.2 | 5.4 ± 0.4 | 19.5 ± 4.0 | 2.1 ± 0.2 | 2 | 6.5 ± 0.9 | 51.5 ± 14.0 |
| HE 015 | 13.6 ± 1.1 | 2.3 ± 0.2 | 5.9 ± 0.6 | 24.5 ± 5.1 | 1.9 ± 0.2 | 3 | 6.3 ± 0.8 | 69.0 ± 8.8 |
| HE 022 | 7.4 ± 0.8 | 1.9 ± 0.1 | 3.8 ± 0.4 | 13.6 ± 2.6 | 4.1 ± 0.4 | 1 | 7.0 ± 0.8 | 78.9 ± 9.5 |
| HE 025 | 13.2 ± 2.7 | 2.3 ± 0.3 | 5.7 ± 0.8 | 29.9 ± 11.6 | 3.2 ± 1.1 | 1 | 7.0 ± 0.7 | 88.1 ± 12.7 |
| HE 035 | 9.2 ± 1.8 | 2.3 ± 0.3 | 4.1 ± 0.9 | 18.5 ± 3.6 | 4.0 ± 0.4 | 2 | 7.9 ± 0.7 | 111.3 ± 13.2 |
| HE 045 | 12.8 ± 1.3 | 1.7 ± 0.1 | 7.6 ± 0.5 | 16.3 ± 3.6 | 4.1 ± 0.5 | 1 | 5.0 ± 0.0 | 62.0 ± 3.7 |
| HE 047 | 11.7 ± 1.3 | 2.1 ± 0.2 | 5.7 ± 0.6 | 17.0 ± 3.0 | 2.4 ± 0.3 | 3 | 5.0 ± 0.0 | 63.9 ± 5.0 |
| HE 047-1 | 11.4 ± 0.9 | 2.1 ± 0.2 | 5.4 ± 0.6 | 16.2 ± 2.9 | 2.8 ± 0.4 | 2 | 5.1 ± 0.3 | 64.2 ± 4.3 |
| HE 050 | 17.0 ± 2.1 | 1.9 ± 0.2 | 9.2 ± 1.1 | 17.4 ± 3.4 | 1.6 ± 0.4 | 2 | 5.2 ± 0.4 | 49.2 ± 8.7 |
| HE 050-1 | 13.3 ± 0.9 | 2.0 ± 0.1 | 6.6 ± 0.5 | 17.2 ± 2.4 | 1.9 ± 0.2 | 3 | 5.7 ± 1.1 | 59.3 ± 8.7 |

(At 6 days after anthesis)

² Fruit color: 1: Yellowish-green, 2: Light green, 3: Green, 4: Dark green, 5: Red.^y Mean ± SD.

The number of loculi: Five loculi were observed in all accessions and cultivars except 'Benny', 'Clemson Spineless', HE 006, HE 015, HE 025 and HE 035 (Fig. 2). The number of loculi was 6.2 ± 0.8 in 'Benny', 6.9 ± 1.3 in 'Clemson Spineless', 6.5 ± 0.9 in HE 006, 6.3 ± 0.8 in HE 015, 7.0 ± 0.8 in HE 022, 7.0 ± 0.7 in HE 025 and 7.9 ± 0.7 in HE 035.

The number of seeds per fruit: The number of seeds per fruit differed from 47.7 ± 5.0 in 'Green Rocket' to 111.3 ± 13.2 in HE 035.

Correlation between flower and fruit characters

Bracteole width, petal number, fruit length, pedicel length and seed number were strongly related with various flower and fruit characters of okra in either positive or negative correlation (Table 4). Bracteole width showed significant positive correlation with bracteole length, petal number, pedicel length and seed number. In contrast, it exhibited significant negative correlation with bracteole number and fruit length. Petal number revealed significant positive correlation with bracteole width, pedicel length, locule number

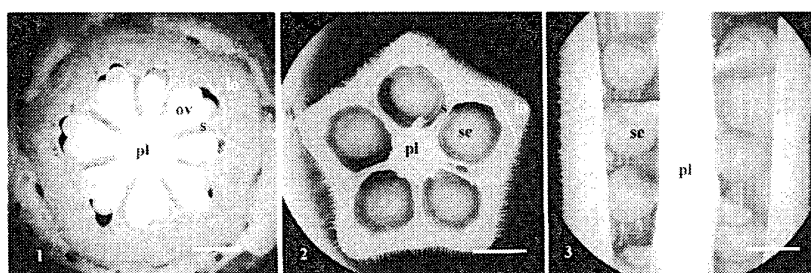


Fig. 2. The number of loculi. 1: Transverse section of HE 015 ovary at anthesis showing eight loculi. 2: Transverse section of 'Green Rocket' fruits at 6 days after anthesis showing five loculi. 3: Longitudinal section of 'Green Rocket' fruits at 6 days after anthesis showing the position of seeds on placenta. lo: Locule, pl: Placenta, ov: Ovule, s: Septum, se: Seed. Bar represented 1 mm in Fig. 2.1 and 5 mm in Fig. 2.2 and 2.3.

and seed number. But it showed significant negative correlation with fruit length. Fruit length exhibited significant negative correlation with bracteole width, petal number and seed number. Pedicel length showed significant positive correlation with bracteole width, petal number, locule number and seed number. Seed number revealed positive correlation with bracteole width, petal number, pedicel length and locule number.

On the other hand, it showed negative correlation with bracteole number and fruit length.

Table 4. Correlation coefficients in flower and fruit characters among twenty cultivars and ten accessions.

| Character | Bracteole | | Petal no. | Fruit | | | Pedicel length | Locule no. | Seed no. |
|------------------|-----------|----------|-----------|----------|----------|---------|----------------|------------|----------|
| | length | width | | length | diameter | weight | | | |
| Bracteole no. | -0.200 | -0.699** | -0.165 | 0.339 | -0.058 | -0.067 | -0.170 | -0.033 | -0.478** |
| Bracteole length | | 0.385* | 0.215 | -0.135 | -0.295 | -0.284 | 0.154 | -0.069 | 0.126 |
| Bracteole width | | | 0.380* | -0.410* | -0.080 | 0.079 | 0.624** | 0.249 | 0.627** |
| Petal no. | | | | -0.536** | 0.022 | -0.166 | 0.566** | 0.676** | 0.728** |
| Fruit length | | | | | -0.068 | 0.455* | -0.352 | -0.199 | -0.455* |
| Fruit diameter | | | | | | 0.609** | -0.185 | 0.240 | 0.233 |
| Fruit weight | | | | | | | 0.079 | 0.375* | 0.253 |
| Pedicel length | | | | | | | | 0.491** | 0.588** |
| Locule no. | | | | | | | | | 0.689** |

*, ** significant at 5% and 1%, respectively.

Cluster analysis

Based on bracteole width, petal number, fruit length, pedicel length and seed number, dendrogram was constructed. According to cluster analysis, 3 clusters were divided as follows (Fig. 3).

Cluster I consisted of 'Natsu no Megumi', 'Peak Five', 'Green Etude', 'Holiday', 'Star Light', HE 047, 'Better Five', HE 047-1, 'Green Rocket', 'Blue Sky', 'Pentagon', HE 015, 'Benny', 'Gulliver', HE 050-1, 'Green Star', 'Miyako Gokaku', 'Star Debut', 'Green Five', 'Suisei Gokaku', 'Early Five', 'Emerald', HE 045.

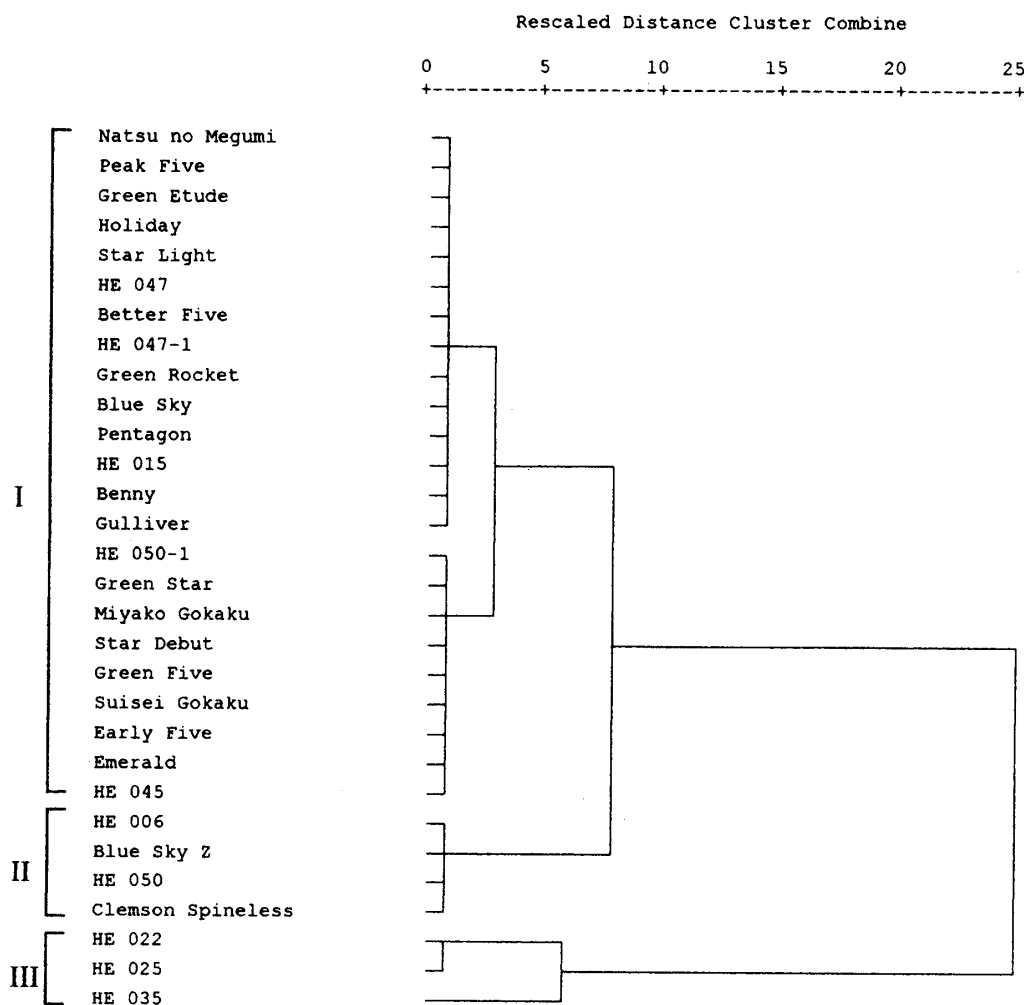


Fig. 3. Dendrogram was constructed by Ward's method based on epicalyx width, petal number, fruit length, pedicel length and seed number of twenty cultivars and ten accessions.

'Better Five', HE 047-1, 'Green Rocket', 'Blue Sky', 'Pentagon', HE 015, 'Benny', 'Gulliver', HE 050-1, 'Green Star', 'Miyako Gokaku', 'Star Debut', 'Green Five', 'Suisei Gokaku', 'Early Five', 'Emerald' and HE 045. The main features were as follows: predominantly five petals, medium fruit (9.7 to 13.6 cm), short pedicle (1.6 to 3.6 cm) and low seed yield per fruit (47.7 to 70.6 seeds per fruit).

Cluster II was composed of HE 006, 'Blue Sky Z', HE 050 and 'Clemson Spineless'. They exhibited mainly five petals, long fruit (11.9 to 17.0 cm), short pedicle (1.6 to 3.5 cm) and low seed yield per fruit (49.2 to 67.8 seeds per fruit).

Cluster III was comprised of HE 022, HE 025 and HE 035. The principal distinguishing features of this cluster were as follows: mainly more than five petals, small fruit (7.4 to 13.2 cm), long pedicle (3.2 to 4.1 cm) and high seed yield per fruit (78.9 to 111.3 seeds per fruit).

Discussion

Flower and fruit characters of twenty cultivars and ten accessions in this study were not so different. In okra flower, an epicalyx was shown at the outermost followed by calyx, petal, stamen and pistil. The component of flower structure was similar to the other Malvaceae, such as *Hibiscus* spp. (Van Borssum Waalkes, 1966) and *Gossypium* spp. (Harward, 1967). In addition, flower organs, e.g., epicalyx, calyx, petal, stamen and pistil of all cultivars and accessions were quite similar in appearance at anthesis.

Okra flowers of all cultivars and accessions in this study showed the five petals except HE 022 and HE 035. The margin of each petal overlapped and rotated either on left-handed or right-handed in the same cultivar or the same flower. Likewise, Weberling (1989) reported that the direction of petal rotation might change within one flower in Malvaceae. Among flower characters, only epicalyx was an important character for species classification of *Abelmoschus* (Van Borssum Waalkes, 1966; Martin, 1982; Siemonsma, 1982). In this study, the epicalyx of all cultivars and accessions was linear in shape and it was much shorter than fruit. The number of bracteoles differed from 8 to 12 and its length varied from 13 to 20 mm. Based on the key to species of Van Borssum Waalkes (1966), twenty cultivars and ten accessions in this study were classified as *Abelmoschus esculentus*.

Okra has been selected primarily for fruit quality and appearance; e.g., shape, size, color and regularity. The young fruits of okra were used mostly as a fresh vegetable. In this study, almost of all cultivars and accessions produced the slender fruits with five ridges or pentagon. Only few of them showed the slender fruits with ridges more than five or slender fruits with ridgeless which showed round shaped. The number of ridges was strongly related to the number of loculi. In this study, the number of loculi was same as the number of ridges. Similarly, the same number of fruit ridges and loculi was also reported in some okra cultivars (Shinohara, 1989). The different number of loculi from five up to eight was observed in this study. However, Hamon and Koechlin (1991), Düzyaman (1997) and Jambhale and Nerkar (1998) noted that there were five to twelve loculi in okra fruits.

Generally, the green fruits were harvested at the young stage about 3 to 6 cm long, before they became fibrous and the seeds were not fully developed (Jambhale and Nerkar, 1998). In this study, fruit length of all cultivars and accessions differed from 7.4 to 17.0 cm at 6 DAA. These indicated that fruit of all cultivars and accessions grew rapidly and they reached marketable size earlier than 6 DAA.

Though an epicalyx was important character in taxonomical classification, it was not so correlated with fruit characters. These implied that fruit in the same species of okra exhibited the similar characters. The significant positive correlation between seed number and flower characters, e.g., epicalyx width, locule number and petal number indicated that high seed yield was possible to select indirectly from these characters. Moreover, the fruits with long pedicel and more locule number might produce more seed number because of the significant positive correlation of these characters.

In terms of cluster analysis, the distances between cluster I and II was less than ten. All cultivars and accessions in both clusters were not so different as five petals, short pedicel and low seed yield per fruit were observed. The only one difference was the long fruit in cluster II and the medium fruit in cluster I. On the other hand, the three accessions in cluster III were distinct from both clusters. They exhibited more than five

petals, short fruit, long pedicel and high seed yield per fruit.

Literature Cited

- Bates, D. M. 1968. Notes on the cultivated Malvaceae 2. *Abelmoschus*. *Baileya* 16: 99-112.
- Bisht, I. S., R. K. Mahajan and R. S. Rana. 1995. Genetic diversity in South Asian okra (*Abelmoschus esculentus*) germplasm collection. *Ann. appl. Biol.* 126: 539-550.
- Düzyaman, E. 1997. Okra: Botany and horticulture. *Hort. Rev.* 21: 41-72.
- Hamon, S. and P. Hamon. 1991. Future prospects of the genetic integrity of two species of okra (*Abelmoschus esculentus* and *A. caillei*) cultivated in West Africa. *Euphytica* 58: 101-111.
- Hamon, S. and J. Koechlin. 1991. The reproductive biology of okra. 1. Study of the breeding system in four *Abelmoschus* species. *Euphytica* 53: 41-48.
- Hayward, H. E. 1967. The structure of economic plants. p. 411-450. Wheldon & Wesley, New York.
- Jambhale, N. D. and Y. S. Nerkar. 1998. Okra. p. 589-607. In: D. K. Salunkhe and S. S. Kadam (eds.). Handbook of vegetable science and technology, production, composition, storage and processing. Marcel Dekker, USA.
- Martin, F. W. 1982. A second edible okra species, and its hybrids with common okra. *Ann. Bot.* 50: 277-283.
- Shinohara, S. 1989. Vegetable seed production technology of Japan. Elucidated with respective variety development histories, particulars. Vol. II. p. 129-140. SAACEO, Tokyo.
- Siemonsma, J. S. 1982. West African okra morphological and cytogenetical indications for the existence of a natural amphidiploid of *Abelmoschus esculentus* (L.) Moench and *A. manihot* (L.) Medikus. *Euphytica* 31: 241-252.
- Van Borssum Waalkes, J. 1966. Malesian Malvaceae revised. *Blumea* 14: 1-251.
- Weberling, F. 1989. Morphology of flowers and inflorescences. p. 1-200. Cambridge Univ. Press, Cambridge.
- Yamaguchi, M. 1983. World vegetables. Principles, production and nutritive values. p. 368-370. Van Nostrand Reinhold Co., USA.

オクラ (*Abelmoschus esculentus*) の花芽並びに果実形態

Panumart Rithichai・藤 目 幸 擴・Sutevee Sukprakarn・
寺 林 敏・伊 達 修 一

摘要：タイで栽培されるオクラの10系統と日本で栽培される20品種を供試して、花と果実の形態的特性を調査した。

開花時には、どの系統・品種でもその外観はほぼ同じであった。果実は五角形あるいは丸形で、細長い形状をしていた。供試したすべての系統・品種は、*Abelmoschus esculentus*に属していた。

10系統と20品種は、クラスター分析により3群に分類された。クラスター1には'Benny', 'Better Five', 'Blue Sky', 'Early Five', 'Emerald', 'Green Etude', 'Green Five', 'Green Rocket', 'Green Star', 'Gulliver', 'Holiday', 'Miyako Gokaku', 'Natsu no Megumi', 'Peak Five', 'Pentagon', 'Star Debut', 'Star Light', 'Suisei Gokaku', HE 015, HE 045, HE 047, HE 047-1とHE 050-1が含まれた。クラスター2には'Blue Sky Z', 'Clemson Spineless', HE 006とHE 050が含まれた。クラスター3にはHE 022, HE 025 と HE 035が含まれていた。