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Morphological Characteristics and Yield of Five Major Cucumber Types under Cultivation in Japan

Yoshiteru Sakata, Mitsuhiro Sugiyama, Yosuke Yoshioka
and Takayoshi Ohara

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I Introduction

The multitude of domestic cucumber（*Cucumis sativus* L.）cultivars grown for fresh consumption worldwide form a smaller number of major types, which include American slicer（slicer）, Dutch greenhouse slicer（greenhouse）, Middle-Eastern slicer（Beit Alpha）, American pickling（pickling）, and oriental trellis slicer（oriental）（Shetty and Wehner, 1998）. The oriental cucumbers comprise at least three types: the North-Chinese type, the South-Chinese type, and the Japanese type（Sakata and Sugiyama, 2002）. The Japanese type cucumbers are hybrids of the North-Chinese and South-Chinese types. The primary differences among the cucumber types are recognized by their fruit sizes（length, length to diameter ratio）, their time to harvest, and fruit-surface conditions（warts, spines, ridges, dimples, and color）. The fruit size and fruit surface characteristics of the major types of cucumbers are diverse and are summarized in Table 1. Besides fruit appearance, other traits differ among the cucumber types, including growth pattern, yield, disease resistance, and internal fruit quality.

Despite the wide variation in cucumbers cultivated worldwide, only the very uniform Japanese-type cucumbers are grown and consumed in Japan（Sakata and Sugiyama, 2002）. The fruits are harvested at about 100g in weight and 22cm in length, are cylindrical in shape, deep green, and have white spines. However, other cucumber types may also offer advantages for Japanese growers and consumers.

Cucumber yield from year-round production（autumn to early summer production）in Japan is far lower, at 100 t/ha/year（MAFF, http://www.maff.go.jp/）, than in the Netherlands, at 700 t/ha/y（FAOSTAT, http://faostat.fao.org/）. This yield difference seems to derive from many factors, including the cultivars grown, fruit size at harvest, cultivation methods, facilities, and climate. Because non-Japanese cucumber types are of potential interest to Japanese growers and consumers, it is important to learn how non-Japanese types will grow under typical Japanese cultural conditions. However, there have been few comparative studies comparing the yield of Japanese and Dutch greenhouse cultivars（Ogiwara and Yuhashi, 1980）.

The current study was conducted to identify the beneficial characteristics of other cucumbers types that may be lacking in Japanese types so as to guide future breeding programs. We cultivated eight cultivars from the five major cucumber types to discern the main morphological characteristics, growth patterns, fruit characteristics, and yield.

Vegetable Breeding Research Team
360 Kusawa, Ano, Tsu, Mie, 514-2392 Japan

Table 1. The characteristics of the fruits and fruit-surfaces of the major types of cucumbers grown in various parts of the world for fresh-market.

Type	Main origin (Country)	Fruit			Fruit surface			Skin thickness
		Harvest size	Length	Length / diameter	Color	Wart	Spine	
Beit Alpha	Middle-East	Medium	Short	Small	Green	(None)	(None)	Thin
Greenhouse	(Netherlands)	Big	Long	Large	Green	(None)	(None)	Thin
Oriental slicer	East Asia							
North-Chinese	(China)	Medium -big	Long	Largest	Green	Medium	White	Thin
South-Chinese	(China)	Medium -big	Medium	Medium	Light green -green	Medium -large	Black	Medium
Japanese	(Japan)	Medium	Medium	Large	Green -dark green	Medium	White	Thin
Pickling [z]	(USA)	Small	Short	Small	Green	Large	White	Medium
Slicer	(USA)	Medium -big	Medium	Small	Dark green	Large	White	Thick

[z] Pickling cucumber is also used for fresh consumption.

II Materials and Methods

1 Cultivars and cultivation methods

We evaluated eight cultivars of five cucumber types: Beit Alpha, greenhouse, Japanese, pickling, and slicer (Table 2, Fig. 1). The Japanese cultivars used were 'Sharp 1' (Saitama Gensyu Ikuseikai Co., Saitama, Japan) and 'Suisei Fushinari' (Kurume Vegetable Breeding Co., Fukuoka, Japan). For a greenhouse type, we chose the Japan-bred 'SK-707' (Sakata Seed Co., Kanagawa, Japan). Other cultivars from each type were chosen for their relatively high disease resistance (Table 2).

The eight cultivars were cultivated four times (spring 2006, autumn 2006, spring 2007, and spring 2008) at the National Institute of Vegetable and Tea Science (Tsu city, Mie, Japan). Seeds were sown in 9-cm-diameter plastic pots filled with sterilized and fertilized seed-raising mix comprising a 1:1 mix by volume of Engei-baido (Kureha Chemical Industry Co., Tokyo, Japan) and *Rakusaku* (Mikado Kyowa Seed Co., Tokyo, Japan). The seedlings were grown in a glass greenhouse. Before the seedlings were planted, 1.5kg • a^{-1} of N, P_2O_5 and K_2O, respectively, were applied to the soil in a plastic (spring and autumn 2006 and spring 2007) or a glass greenhouse (spring 2008). The seedlings were planted 0.4 m (or 0.5 m) apart in single-row plots, with a distance of 1.5 m between rows. The soil surface of the rows was covered with a mulch of black polyethylene film (0.03 mm thick). The vents of greenhouses were covered with plastic screens having a 1.0-mm mesh to exclude pollinator insects. The minimum air temperature was 15℃ and ventilation temperature was 27℃.

Two methods were adopted for training the cucumber plants: the *teki-shin* method and the high-wire method. *Teki-shin* is a common Japanese training method that involves (1) supporting and training the primary vine up a vertically strung cord, (2) topping the primary vine at the 18 th to 20 th node, and (3) pinching off the first and secondary lateral branches at the first or second node (Fujieda, 2006). The high-wire training method that we used involved (1) supporting and training the primary vine up a long vertically strung cord, (2) pruning all lateral branches, and (3) harvesting fruits from the primary vine. The high-wire training method was conducted in a glass-made greenhouse (ceiling height of ca. 3.4 m) with the horizontal wire from which training cords were suspended at a height of ca. 2.6 m.

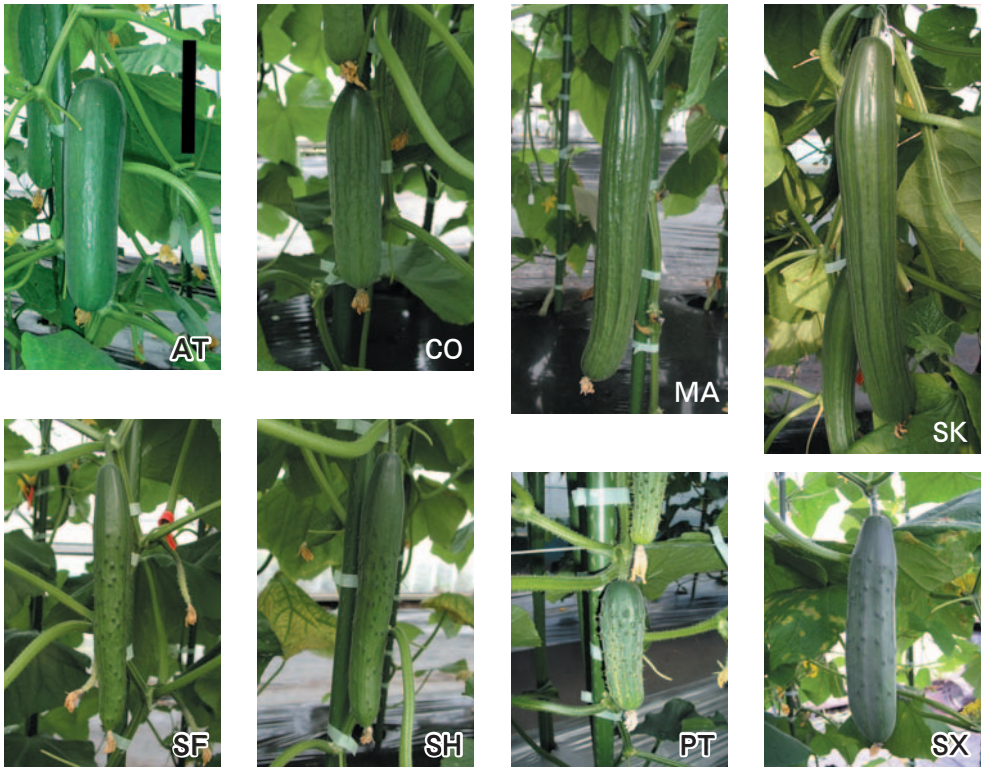

Fig. 1 Photographs of the fruits of eight cultivars from five major cucumber types used in this study. The black bar represents 10cm. Abbreviations: AT－Atar; CO－Condesa; MA－Marianna; SK－SK-707; SF－Suisei Fushinari; SH－Sharp 1; PT－Patton; SX－SXQS 2184.

Table 2 The cucumber cultivars evaluated in this study and descriptions of their major features as supplied by the seed supplier.

Cultivar (abbr.)	Type	Description and standard fruit size for harvest	Source
Atar (AT)	Beit Alpha	Suitable for spring and autum. Adapted to pruning. Resistant/torelant to powdery mildew (PM) and Fusarium wilt. 18－20 cm (160 g)	Hazera Genetics Ltd., Israel
Condesa RZ (CO)	Beit Alpha	Suitable for all growing season. Early production. Highly resistant/torelant to PM. 15－18 cm (110 g)	Rijk Zwaan Export B.V, the Netherlands
Marianna RZ (MA)	Greenhouse	Suitable for spring to fall. Midium early production. Highly resistant/torelant to PM and Scab. 25－30 cm (210 g)	Rijk Zwaan Export B.V, the Netherlands
SK-707 (SK)	Greenhouse	(unknown) 30 cm (240 g)	Sakata Seed Co., Japan
Suisei Fushinari (SF)	Oriental slicer (Japanese)	Suitable for autumn to spring. All famale. 20－22 cm (100 g)	Kurume Vegetable Breeding Co. Ltd, Japan
Sharp 1 (SH)	Oriental slicer (Japanese)	Suitable for all growing season. High productivity. 20－22 cm (100 g)	Saitama Gensyu Ikuseikai Co., Japan
Patton (PT)	Pickling	For hand harvest. Resistant/torelant to Scab, PM, downy mildew (DM), anthracnose (Anth) and Cucmber mosaic virus (CMV). 10 cm (60 g)	SunSeeds Ltd, USA (present: Nunhems USA Inc, USA)
SXQS2184 (SX)	Slicer	Early production. Resistant/torelant to Scab, CMV, PM, DM, Anth, Papaya ringspot virus, Watermelon mosaic virus 2 and Zucchini yellow mosaic virus. 20 cm (220 g)	SunSeeds Ltd, USA (present: Nunhems USA Inc, USA)

2 Evaluation of morphological characteristics

To evaluate plant morphological characteristics, we planted two replicates of six seedlings (transplanted 15 days after sowing) of each cultivar on 17 August 2006 in a plastic greenhouse. To evaluate fruit morphological characteristics, we planted two replicates of four seedlings (22 days after sowing) of each cultivar on 29 February 2008. These plants were also used for yield evaluation in 2008.

The data were recorded according to the descriptors for the characterization and evaluation of plant genetic resources (National Institute of Agrobiological Sciences, Genebank, Tsukuba, Ibaraki, Japan. http://www.gene.affrc.go.jp/manuals_en.php). We measured 50 characteristics, but in this paper we report the results for 12 plant and 15 fruit characteristics, some of which are quantitative measures whereas others are descriptive classifications.

3 Evaluation of the fruit growth pattern

To determine the growth pattern of the fruit in each cultivar, we measured the length, diameter and weight of fruits at 7, 10, 14, and 17 days after anthesis. Five seedlings (at age 21 days after sowing) in four replications of each cultivar were planted in a plastic greenhouse on 12 April in 2006 and trained using the *teki-shin* method. We repeated this cultivation in 2007 with planting on 20 April (25 days after sowing), this time with two replicates. All female flowers or small fruits were removed until the start of measurements to reduce the fruit load. Fruits of 'Atar' (AT), 'Condesa' (CO), 'Marianna' (MA), 'Sharp 1' (SH) and 'SK-707' (SK) were measured in the 2006 cultivation and those of 'Patton' (PT), 'Suisei Fushinari' (SF), SH, and 'SXQS 2184' (SX) were measured in the 2007 cultivation. Female flowers that were at anthesis on the same day were labeled and the growing fruits harvested according to the treatment (i.e., 7, 10, 14 or 17 days after anthesis).

4 Yield evaluation

Yields were evaluated in the spring 2008 cultivation in a glass greenhouse (see descriptions of planting conditions in the preceding sections). Because different training methods may cause differences in growth and the fruit-bearing habit, we compared results from *teki-shin* and high-wire training. The central part of the greenhouse with higher ceiling (ca. 3.4 m) was used for high-wire training method and both sides with lower ceiling (ca. 2.5 m) were used for *teki-shin* training method. The *teki-shin* training method was used for all cultivars, whereas the high-wire training method was used for only the Beit Alpha, greenhouse, and Japanese-type cultivars.

Fruits were harvested every day for yield evaluation at the standard sizes recommended by the seed suppliers (Table 2). The total yield of each cultivar was summed for each two-week period from the first harvest to the end of harvest.

Ⅲ Results

1 Evaluation of morphological characteristics

In regard to plant morphological characteristics (Table 3), the different cucumber types were clearly differentiated, but similar results were observed between the cultivars within each type. The cotyledons of the Beit Alpha cultivars (AT and CO) and greenhouse cultivars (MA and SK) were longer and had a larger length to width ratio than those of the Japanese cultivars (SF and SH), pickling type (PT), and slicer type (SX). Cultivars AT, CO, MA, and SK tended to have taller plants, larger leaves, and longer petioles than those of SF, SH, PT and SX. The leaf color was lighter in AT, CO, MA, and SK than in SF, SH, PT, and SX. In general, the plant form of the greenhouse and Beit Alpha types was larger than that of the Japanese, pickling, and slicer

types. The Beit Alpha types displayed a close resemblance to the greenhouse types, but were slightly shorter.

All cultivars had a high frequency of lateral shoot emergence. SH, PT, and SX were monoecious, whereas AT, CO, MA, SK, and SF were gynoecious. Fruits set at the main vines and lateral branches in every cultivar except SX. However, there were some female flowers on the main vines in SX in the spring 2008 cultivation (data not shown). Every cultivar displayed parthenocarpy.

In regard to fruit characteristics (Table 4), SF, and SH required the fewest days to reach fresh market size (harvest) from anthesis, whereas MA, SK, and SX required the most. Fruit shape was cylindrical in all

Table 3 Measured and observed plant characteristics of the eight cucumber cultivars in the autumn 2006 cultivation.

Cultivar	Length of cotyledon [z] (mm)	Length / width of cotyledon [z]	Plant height [y] (cm)	Inter-node length [y, x] (cm)
Atar (AT)	56.1 ab [t]	1.88 bcd	152.5 a	7.6 b
Condesa (CO)	54.4 b	1.95 ab	128.4 bc	7.5 bc
Marianna (MA)	59.5 a	1.92 abc	151.6 a	8.6 a
SK-707 (SK)	55.9 ab	2.03 a	145.3 a	8.9 a
Suisei Fushinari (SF)	46.8 cd	1.78 d	131.5 b	7.6 bc
Sharp 1 (SH)	44.3 d	1.62 e	116.7 cd	7.2 c
Patton (PT)	50.1 c	1.88 bc	127.0 bc	7.4 c
SXQS2184 (SX)	50.1 c	1.80 cd	114.5 d	8.3 ab

Table 3 Measured and observed plant characteristics of the eight cucumber cultivars in the autumn 2006 cultivation. (cont.)

Cultivar	Thickness of stem [y] (mm)	Leaf size [y, w] (cm)	Length of petiole [y, w] (cm)	Leaf color
Atar	6.6 cd	32.1 b	22.5 a	Light green
Condesa	8.5 a	29.1 c	19.6 b	Light green
Marianna	7.9 b	33.1 ab	23.7 a	Light green
SK-707	6.1 de	34.2 a	23.4 a	Light green
Suisei Fushinari	7.0 c	26.8 d	16.3 c	Green
Sharp 1	6.4 d	22.9 f	13.7 d	Green
Patton	5.7 e	24.2 ef	16.5 c	Slightly dark green
SXQS2184	6.2 d	25.7 de	17.2 c	Green

Table 3 Measured and observed plant characteristics of the eight cucumber cultivars in the autumn 2006 cultivation. (cont.)

Cultivar	Emergence of lateral shoot [v] (%)	Sex type	Fruit bearing position [u]	Parthenocarpy
Atar	98	Gynoecious	M + L	Present
Condesa	98	Gynoecious	M + L	Present
Marianna	100	Gynoecious	M + L	Present
SK-707	98	Gynoecious	M + L	Present
Suisei Fushinari	95	Gynoecious	M + L	Present
Sharp 1	100	Monoecious	M + L	Present
Patton	100	Monoecious	M + L	Present
SXQS2184	100	Monoecious	L	Present

[z] Measured at the first true leaf expanding stage.
[y] Measured at one day before the main stem is topped.
[x] Average length of 10th to 15th inter-nodes.
[w] 10th leaf.
[v] Percentage of primary lateral shoots from the 6th to 15th nodes of main stem.
[u] M + L: Main vein and lateral branches, L: Lateral branches.
[t] Different letters indicate significantly different means within columns (Ryan's multiple range tests, $P < 0.05$).

cultivars. Fruit skin color was dark green in SF, SH, and SX; all others were green, but PT also had yellow stripes. Large to intermediate skin warts were present on SF, SH, PT, and SX, whereas few, very small warts were present on the skins of AT, CO, MA, and SK. The spines were white in all cultivars.

The cultivars MA, SK, and SX had the heaviest fruit (at fresh market size), at over 200 g, whereas the fruits of CO, SF, and SH at the same stage were around 100 g. PT had the lightest fruit at ca. 60 g. MA and SK had the longest fruit; SF and SH had the second-longest fruit, followed by AT, CO, SX, and PT. The ratio of fruit length to width tended to be higher in MA, SK, SF, and SH, and was lowest in PT. The ratio of flesh thickness to fruit diameter (i.e., the relative flesh thickness) tended to be higher in MA, SK, SF, and SH.

Table 4 Measured and observed fruit characteristics at maturity for table use of the eight cucumber cultivars in the spring 2008 cultivation.

Cultivar	Days from anthesis to fruit harvest (days)[z]	Fruit shape	Fruit color	Pattern of fruit surface	Depth of furrow on fruit surface
Atar (AT)	13.2 bc[y]	Cylindrical	Green	Absent	Very shallow
Condesa (CO)	12.3 cd	Cylindrical	Green	Absent	Shallow
Marianna (MA)	15.0 a	Cylindrical	Green	Absent	Rather deep
SK-707 (SK)	13.7 ab	Cylindrical	Green	Absent	Rather shallow
Suisei Fushinari (SF)	11.1 d	Cylindrical	Dark Green	Absent	Very shallow
Sharp 1 (SH)	9.3 e	Cylindrical	Dark Green	Absent	Shallow
Patton (PT)	not checked	Cylindrical	Green	Yellow stripe (half)	Shallow
SXQS2184 (SX)	14.8 ab	Cylindrical	Dark Green	Absent	Smooth

Table 4 Measured and observed fruit characteristics at maturity for table use of the eight cucumber cultivars in the spring 2008 cultivation. (cont.)

Cultivar	Density of warts of fruit	Wart size of fruit	Fruit spine color	Fruit weight (g)	Fruit length (cm)
Atar	Very low	Very small	White	163.5 c	18.7 e
Condesa	Very low	Very small	White	109.1 d	15.9 f
Marianna	Very low	Very small	White	205.8 b	27.5 b
SK-707	Very low	Very small	White	235.3 a	31.8 a
Suisei Fushinari	Intermediate	Intermediate	White	101.6 d	22.4 c
Sharp 1	Intermediate	Intermediate	White	97.9 d	22.6 c
Patton	Intermediate	Large	White	63.3 e	10.5 g
SXQS2184	Intermediate	Large	White	222.3 ab	19.9 d

Table 4 Measured and observed fruit characteristics at maturity for table use of the eight cucumber cultivars in the spring 2008 cultivation. (cont.)

Cultivar	Fruit width (cm)	Fruit length / fruit width	Placental diameter (cm)	Flesh thickness / fruit width	Flesh color
Atar	3.60 b	5.2 d	2.16 b	0.40 f	Milky green
Condesa	3.15 cd	5.1 de	1.72 d	0.45 d	Milky green
Marianna	3.29 c	8.4 c	1.51 d	0.54 a	Milky green
SK-707	3.15 cd	10.1 a	1.51 d	0.52 bc	Milky green
Suisei Fushinari	2.51 e	9.0 b	1.20 e	0.52 bc	Milky green
Sharp 1	2.43 e	9.3 b	1.18 e	0.51 c	Milky green
Patton	2.97 d	3.5 f	1.71 c	0.42 ef	Milky green
SXQS2184	4.21 a	4.8 e	2.36 a	0.44 de	Milky green

Fruits were harvested during 13 April−25 April, 2008. Fifteen fruits were sampled for each cultivar.
[z] The data of the days from the anthesis to fruit harvest was checked from 4−19 fruits.
[y] Different letters indicate significantly different means within columns (Ryan's multiple range tests, $P < 0.05$).

2 Growth patterns of fruits

The growth patterns of cucumber fruit from anthesis are shown for the eight cultivars in Figure 2. Fruit weight and length increased almost linearly up to 17 days after anthesis in every cultivar.

In the spring 2006 cultivation, the heaviest and longest cultivar after 17 days was SK (greenhouse type; 1,334 g and 49.4 cm). The greenhouse type MA, Japanese type SH, and Beit Alpha type CO followed. The fruit of CO exceeded 1,000 g, whereas the other Beit Alpha type cultivar, AT, had the lightest (661 g) and shortest (25.9 cm) fruit. Notably, the Japanese cultivar SH was almost as heavy (1,129 g) and long (46.1 cm) as the greenhouse-type cultivars.

In the 2007 spring cultivation, the heaviest and longest cultivars were the Japanese cultivars SF and SH. Their weight and length at 17 days after anthesis were 1,543 g and 48.8 cm, respectively, for SF and 1,344 g and 46.7 cm, respectively, for SH. The slicer type SX followed. PT, the pickling-type cultivar, was lightest (670 g) and shortest (19.5 cm). There was a large difference in the rate of fruit growth between the 2006 and 2007 cultivations. The fruit weight of SH at 7 days after anthesis in 2006 was 70.2 g, whereas in 2007 it was 306.2 g. The data were obtained in May to June in both years in the same plastic greenhouse; however, the weather in 2007 was generally fine and sunny, whereas in 2006 there were few fine days and many rainy days.

The clearest trend emerging from the results was that the heaviest and longest cultivars were of the greenhouse and Japanese types, and the lightest and shortest was the pickling cultivar.

3 Yields

The yield patterns of the eight cultivars trained by the *teki-shin* method (abbreviated as -ts) and the subset of six cultivars representing the Beit Alpha, greenhouse, and Japanese types trained by the high-wire method (-hw) are shown in Figure 3. As with the results for early yield (from first harvest to the 4 th week), the Beit

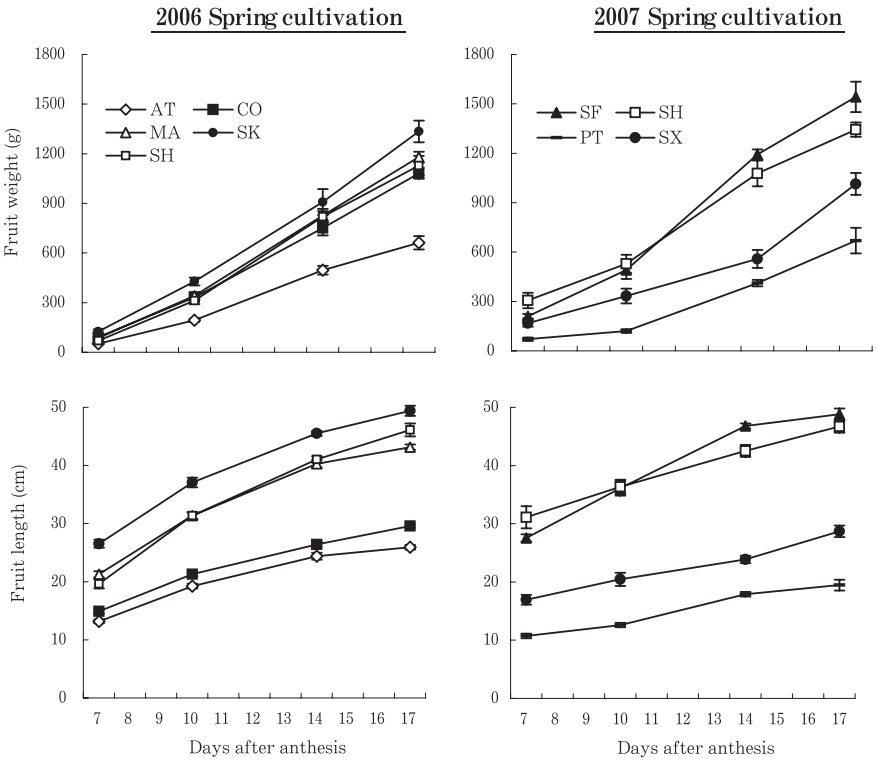

Fig. 2 Patterns of increase over time from anthesis in cucumber fruit weight and length. Data points are means ± SE (n = 3－14). Abbreviations: AT－Atar; CO－Condesa; MA－Marianna; SK－SK-707; SF－Suisei Fushinari; SH－Sharp 1; PT－Patton; SX－SXQS 2184.

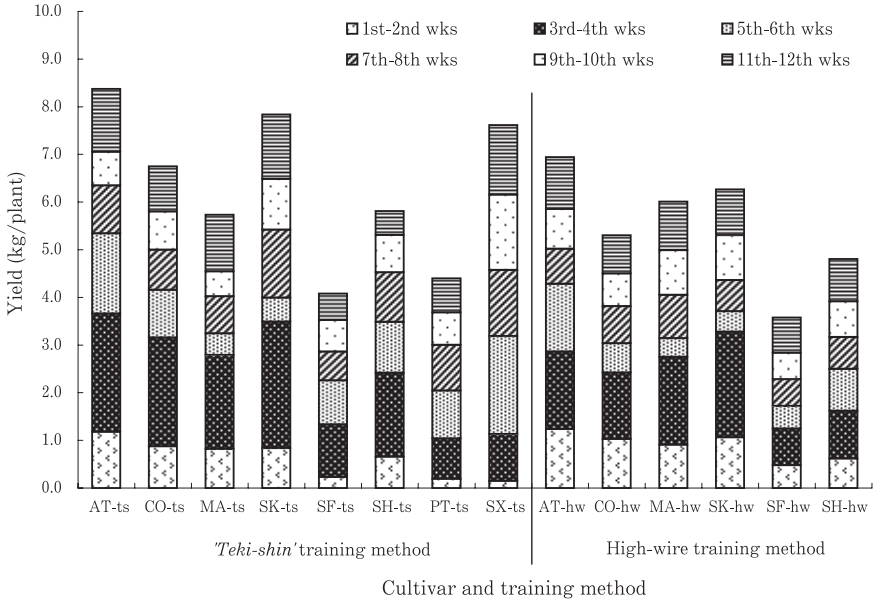

Fig. 3 Patterns in the yield in successive periods of time following the commencement of anthesis in the eight cucumber cultivars in the spring 2008 cultivation. Abbreviations: AT－Atar; CO－Condesa; MA－Marianna; SK－SK-707; SF－Suisei Fushinari; SH－Sharp 1; PT－Patton; SX－SXQS 2184; Abbreviation suffixes: -ts－*teki-shin* training method; -hw－high-wire training method.

Alpha cultivars (AT and CO) and the greenhouse cultivars (MA and SK) produced higher yields than the Japanese, pickling, and slicer cultivars (SF, SH, PT, and SX). The highest total yield was obtained from AT-ts. The total yields of SK-ts, SX-ts, AT-hw, CO-ts, SK-hw, and MA-hw followed. The total yields of the Japanese SF cultivar were the lowest.

IV Discussion

The Beit Alpha and greenhouse cultivars were vigorous and produced larger plants with larger leaves and longer petioles than the Japanese cultivars. In Japan, cultivars with smaller leaves are believed to be better suited to the *teki-shin* training method. However, Matsuura and Fujita (1995) pointed out that the number of fruit was correlated with leaf size in a comparative study of 98 cucumber cultivars. Presumably, larger plants provide greater photosynthetic product to support a larger fruit load. In the current study, the early (1 st－4 th week) yields of the Beit Alpha and greenhouse types were higher than those of the Japanese, pickling, and slicer types. However, in the subsequent period (5 th－6 th weeks), the yields of the Beit Alpha and greenhouse cultivars clearly declined, whereas the lower yielding cultivars continued to produce at about the same rate. The initial heavy fruit-set on the main vines and first lateral branches presumably brought about an exhaustion of the plants. The total yields of the Beit Alpha and greenhouse cultivars were greater than those of the Japanese and pickling types. Wehner and Horton (1986) also reported that Beit Alpha cucumbers yielded better under open-field conditions in North Carolina, USA, than Japanese, pickling, and slicer cucumbers. The slicer type SX also achieved a high total yield after a slow start. The reason for this higher yield from SX was not clear, but it may have been related to the initial low fruit load of this cultivar in the 1 st to 4 th weeks. To attain higher yields in cucumber production through breeding, we should re-evaluate the practice of selection based on traits related to large plant form, such as large leaf size. We should also consider the total cultivation system, including training method, planting density, nutrition management, and greenhouse structure to achieve the best balance between plant growth and fruit load.

The yields from *teki-shin* training were higher than those from high-wire training in each cultivar except greenhouse MA. The main reason for the lower yields from the high-wire training method is considered to be the loss of yield from the first lateral branches. Isomura et al. (2001) also reported that the yield of vertical training (high-wire training) was inferior to that of the *teki-shin* training method. However, the high-wire training method is not necessarily inferior to the *teki-shin* training method. The high-wire training method, and the associated cultivation system, has not been widely adopted in Japan, and our crude attempts at high-wire training may not have produced the best possible results from this system. Further investigations into the establishment of the high-wire training method and the associated cultivation system under Japanese conditions need to be carried out.

Fruits of greenhouse and slicer cultivars are harvested for the fresh market at large sizes (200－300 g), whereas fruits of Japanese-type cucumbers are harvested at ca. 100 g. However, the fruit-growth pattern results in the current study showed that Japanese cultivars are able to produce fruit almost as heavy and long as the greenhouse cultivars. This implies that the fruits of the Japanese type are typically harvested at a very early stage of development. Because fruit growth is very rapid at this early stage, and the Japanese fruit-size standard for shipping to fresh market allows little tolerance, farmers often harvest fruits twice a day from spring to autumn (Sakata et al., 1998). This is a labor-intensive harvesting system. By using a greenhouse-type cultivar (harvested at ca. 300 g), harvesting can be reduced to four times per week (Y. Yamamoto, Fukuoka Agricultural Research Center, personal communication). Ogiwara and Yuhashi (1980) also noted that harvesting larger fruit produced a higher overall yield than harvesting smaller fruit in a trial with a greenhouse-type cultivar. The appropriate fruit size for harvest needs to be reconsidered from the viewpoints of saving labor and increasing yield.

The very small warts and spines that we observed on the fruit surface of the Beit Alpha and greenhouse cultivars is an attractive trait in the food industry. The fruits of the common cultivars of Japanese-type cucumbers are regarded as harboring higher levels of microorganisms than other vegetables (Izumi, 2005) because they possess warts, spines, and scars, and arguments have been presented that the cucumber is unsuitable for use as a fresh-cut vegetable. However, the cucumber remains one of the more important vegetables to the food industry in Japan, especially for preparing fresh salads, Japanese *kappa-maki* sushi, and sandwiches. The availability of cucumbers with fewer warts, spines and scars may allay fears of contamination. Two new Japanese cultivars, 'Freedom' (Sakata Seed Co.) and 'Polish' (Nihon Horticultural Production Institute, Chiba, Japan), possess such traits and are becoming more widely used in the food industry. But the fruit of 'Freedom' has a softer texture than that of common Japanese cucumber cultivars. Fruit qualities such as texture also need to be carefully considered when breeding new cucumber cultivars.

This comparative study of the morphological characteristics, fruit growth patterns, and yield of the major cucumber types was a first step towards identifying beneficial characteristics of other cucumber types that are lacking in Japanese-type cucumber cultivars. We discovered several attributes that deserve further attention in cucumber breeding: plant form, fruit surface condition, and fruit size at harvest. Because cultivar development and improvements to the cultivation system progress together, the latter, including the vine training method, needs further scrutiny for Japanese conditions.

Summary

We evaluated the morphological characteristics, fruit growth pattern, and yields of eight cultivars representing five types of cucumber (*Cucumis sativus* L.). The cucumber types examined were Beit Alpha, greenhouse, Japanese, pickling, and slicer. The different cucumber types were clearly differentiated from one

another, but displayed similar values between cultivars of each type. Cultivars of the greenhouse and Beit Alpha types produced larger leaves and plants (height and length) and longer petioles than cultivars of the Japanese, pickling, and slicer types. Large to intermediate-sized warts occurred on cultivars of the Japanese, pickling, and slicer types, whereas few, small warts occurred on cultivars of the greenhouse and Beit Alpha types. Fruit weight (at harvest for the fresh market stage) of greenhouse and slicer type cultivars exceeded 200g, whereas the fruit weight of Japanese and Beit Alpha type cultivars was around 100g and the pickling type cultivar produced the lightest fruit, at ca. 60g. The heaviest and longest fruits at 17 days after anthesis were produced by the cultivars of the greenhouse and Japanese types (weight > 1,100g, length > 43cm) and the lightest and shortest fruit were from the pickling type cultivar (< 700g, < 20cm). Early yields were higher in the Beit Alpha and greenhouse cultivars than in the cultivars of the Japanese, pickling and slicer types, and total yields were higher in the Beit Alpha, greenhouse, and slicer cultivars. Yields produced by the high-wire training method were inferior to those from the Japanese *teki-shin* training method. This evaluation suggests that further breeding should focus on traits related to plant form, fruit surface condition, and fruit-size at harvest.

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日本の栽培条件下における主要5タイプのキュウリの形態的特性と収量

坂田　好輝・杉山　充啓・吉岡　洋輔・小原　隆由

摘　要

世界で栽培されるキュウリ（*Cucumis sativus* L.）には，形態・特性に多様性があることが知られているが，我が国で栽培されているキュウリはきわめて画一的で，かつ日本独特である．多様なキュウリの中には，我が国のキュウリ生産の画期的な進展につながる特性や形質，収量性を有する可能性がある．しかし，日本型キュウリを含む主要なキュウリタイプについて，それぞれの特性・形質を具体的に示し，さらに，それらの特性・形質の有用性について詳細に検証した報告はみあたらない．

そこで，本報告では，各特性・形質の詳細な解析につなげるための基礎資料となる具体的なデータを得ることを目的に，世界および日本で栽培されている主要な5タイプのキュウリ(温室，スライス，ピクルス，ベイトアルファおよび日本)の合計8品種を栽培し，それらの形態，果実の成長および収量を比較した．

同じタイプに属する品種間の特性・形質は極めて似ていたが，タイプ間ではそれぞれ明瞭な差異が認められた．以下にその特性・形質を述べる．日本型キュウリ，スライスタイプおよびピクルスタイプに比べて，温室タイプおよびベイトアルファタイプの草姿は大きく，草丈は高い傾向にあり，葉柄長は長く，そして葉幅は大きかった．日本型キュウリ，スライスタイプおよびピクルスタイプの果実には大～中サイズのイボがあったが，温室タイプおよびベイトアルファタイプではほとんど無いか，微小であった．温室タイプとスライスタイプの果実（生食用）は200g を超えていた．一方，日本型キュウリおよびベイトアルファタイプの果実は 100 g 程度であり，ピクルスタイプは最も軽く，60 g 程度であった．開花 17 日後において，最も重く，長かったのは温室タイプと日本型キュウリであり，1,100 g，43 cm 以上であった．最も軽く，短かったのはピクルスタイプで，700 g，20 cm 未満であった．

初期収量は，日本型キュウリ，スライスタイプそしてピクルスタイプに比べて，温室タイプおよびベイトアルファタイプにおいて高かった．総収量では，温室タイプ，ベイトアルファタイプとともにスライスタイプも高かった．今回の栽培におけるハイワイヤー栽培での収量は，わが国の代表的栽培方法である摘心栽培に比べ低かった．

以上の結果から，将来の画期的なキュウリ品種の育成のためには，草型，果実表面の状態，そして収穫果実の大きさについて，今後特に注意を払って詳細な比較検討を行う必要があると考えられた．

〒514－2392　三重県津市安濃町草生 360
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