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Screening of Mulberry Genotypes Suitable for Fruit Production and Development of High-Yielding Strains with Large Fruits

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Abstract

In order to screen mulberry genotypes suitable for fruit production, fruit traits of 260 genotypes were examined. Forty-three genotypes were classified into staminate, 137 were pistillate and 78 were hermaphrodite. Fruit quantity and size showed wide variations among the genotypes. Itouwase, Shizensei-roso and Tenmokuyotsume bore more fruits than the other genotypes. Okaraguwa bore the largest fruits, which were 4.9 cm long and weighed 7.15 g. The sugar content of the fruit ranged from 6.6 to 20.8%, and the highest content was observed in Myurienoaaru. Most of the taste panelists rated Okaraguwa and Kataneo higher than the other genotypes. Thus, these 2 genotypes were selected as the most suitable for fruit production. In the next step, we attempted to develop polyploids from these genotypes by colchicine treatment to achieve a high productivity. After the treatment, we propagated the shoots with putative tetraploids to obtain the strains. The 2 strains thus developed were mixoploids of diploids and tetraploids, but it is considered that they were both peripheral chimeras and that their structure remained stable. One of the strains, FRM-01 developed from Kataneo, bore many fruits in the second year after planting in the field. Almost all the fruit traits of this strain were the same as those of the original strain, except that the size became larger and the fruit yield was increased by about 60%.

Discipline: Sericulture / Horticulture / Genetic resources / Plant breeding
Additional key words: colchicine treatment, polyploid, mixoploid, chimera, taste test

Introduction

In Japan, mulberry has been cultivated as diet for silkworms since sericulture was introduced from China more than 2,000 years ago. Eliminating fruit was considered to be one of the most important characters for mulberry breeding, because the mulberry fruit was not necessary for sericulture. However, the mulberry fruit is grown in many European and Middle Eastern countries and in Japan, it has recently been evaluated as a product that could stimulate upland farming. Some special products processed from mulberry fruits, such as jam and wine, are sold all over Japan. An increasing number of reports on mulberry fruit have been published. For example, Iijima and Oshigane screened many mulberry genotypes for the production of jam[1] and Tanaka and Tachibanada analyzed the contents of sugar and organic acids for the production of mulberry wine[7]. However, mulberry varieties suitable for fruit production have not been adequately investigated.

We have collected, maintained and evaluated a large number of genetic mulberry resources at the National Institute of Sericultural and Entomological Science[3] to promote the use of these resources. In the first step, the fruit traits of 260 mulberry genotypes were examined to screen the genotypes suitable for fruit production. Then, we attempted to develop polyploids from the selected genotypes to achieve a high productivity by colchicine treatment.

Materials and methods

1) Screening of genotypes suitable for fruit production

In the present study, we examined 260 genotypes, which have been cultivated by conventional methods since they were planted in the field of our institute 12 years ago. Eighty-two genotypes belonged to *Morus*

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bombycis, 67 to *M. alba* and 104 to *M. latifolia*. The remaining 7 genotypes belonged to other *Morus* species. We observed the inflorescence in May, and then examined fruit traits such as fruit number and size, sugar content and number of seeds per fruit in June, except for the staminate and non-flowering genotypes. Examination of fruit traits was based on the Manual for the Characterization and Evaluation of Mulberry Genetic Resources[5]. Sugar content (Brix %) in a fruit was determined with a PR-1 digital refractometer (Atago Co., Ltd.) and calculated as the mean of 5 ripe fruits. The taste of the raw mulberry fruit was evaluated by 6 panelists, for sweetness, acidity, edibility, etc., using 10 genotypes which bore a large quantity of fruits or fruits with a large size.

2) Development of strains with large fruits

For the 2 genotypes screened, the buds of the potted plants were treated with a 0.1% colchicine solution for 5 days at the sprouting stage to produce the tetraploid plants. After treatment, the plants were pruned several times to eliminate their partial chimera structure, and then root grafting was performed to propagate the shoots that were assumed to be morphologically polyploid. To determine the number of chromosomes, young leaves at shoot apices were sampled, and fixed in ethanol-acetic acid (3:1) for 24 h. The fixed samples were macerated in 1N HCl for 7 min at 58°C. Squash preparations stained by aceto-orcein were observed under a microscope to count the number of chromosomes. To observe the chimera structure, the shoot tips were fixed in FAA (formalin-acetic acid-70% ethanol, 18:1:1) for 24 h, dehydrated through a tertiary butyl alcohol series, embedded in paraffin, cut into 10 μm longitudinal sections and stained by Delafield's hematoxylin. The sizes of the nuclei in the shoot apices were examined on prepared slides.

Results and discussion

1) Screening of genotypes suitable for fruit production

Based on the studies of the inflorescence, 43 genotypes were classified into staminate, 47 predominantly staminate, 15 hermaphrodite, 16 predominantly pistillate and 137 pistillate genotypes (Fig. 1). Two genotypes were not identified because they did not show flowers. Fruit quantity and size displayed significant variations among the genotypes. Itouwase, Shizensei-roso and Tenmokuyotsume bore more fruits than the other genotypes, and many fruits were distributed uniformly from the top branches to the bottom ones. However, some genotypes did not bear fruits, such as Isen K, Miran 4 and Rosou.

Fruit size ranged from 0.9 to 4.9 cm, with a mean of 2.0 cm (Table 1). Onnakunitomi showed the smallest size and Okaraguwa the largest one. Fig. 2 shows that the fruits of the *M. latifolia* genotypes tended to be larger than those of the other species, peaking at 2.1 to 2.5 cm. In almost all the genotypes, the fruit weight was less than 2 g, with only 6 genotypes bearing fruits weighing more than 3 g (Appendix). Okaraguwa bore fruits weighing 7.15 g, which were by far the largest. As shown in Fig. 3, the genotypes belonging to *M. bombycis* tended to bear small fruits, most of which were less than 1 g, while the fruits of the *M. alba* and *M. latifolia* genotypes tended to weigh 1 to 2 g.

Table 1. Fruit traits of 260 mulberry genotypes

	Fruit length (cm)	Fruit weight (g)	Sugar content (Brix%)
Range	0.9–4.9	0.17–7.15	6.6–20.8
Mean	2.0	1.32	11.6
Standard deviation	0.5	0.85	2.3
Deviation efficiency (%)	25.2	64.37	19.4

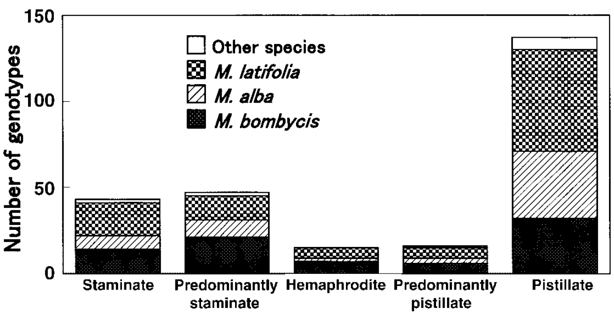


Fig. 1. Inflorescence of 260 mulberry genotypes

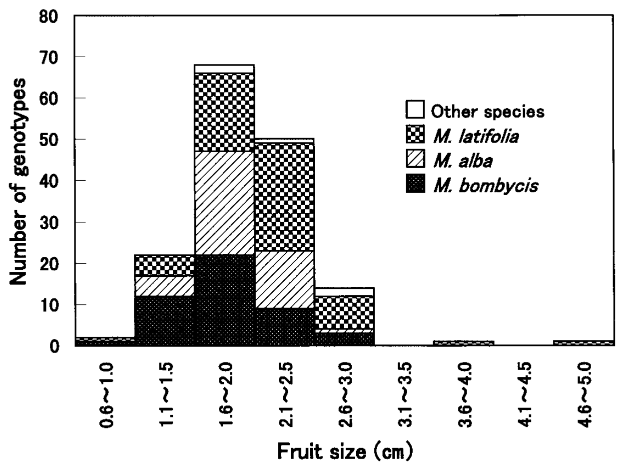


Fig. 2. Fruit size distribution of 260 mulberry genotypes

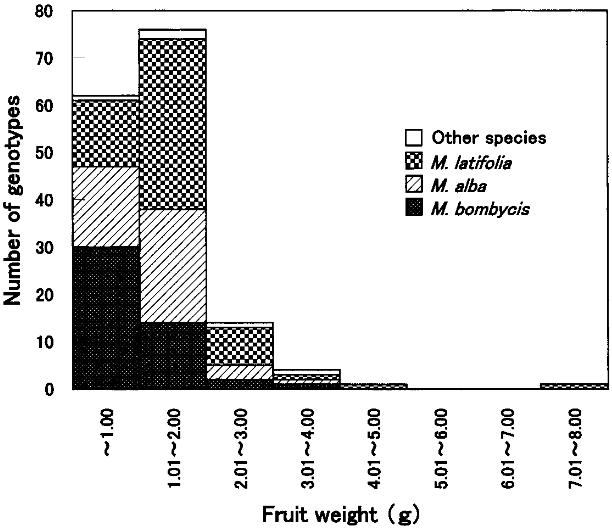


Fig. 3. Fruit weight distribution of 260 mulberry genotypes

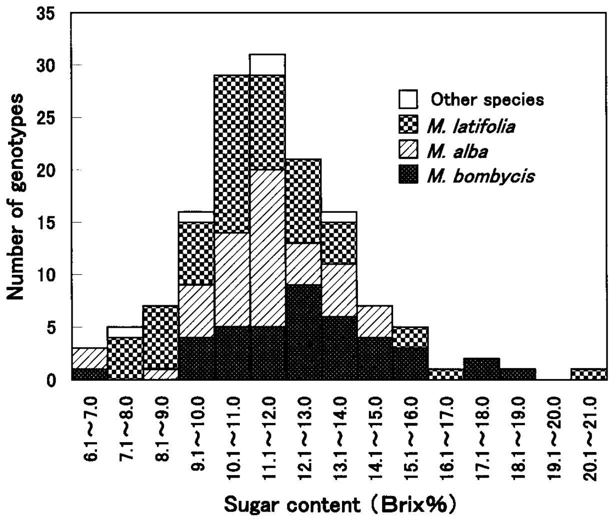


Fig. 4. Sugar content distribution of 260 mulberry genotypes

The sugar content of the fruits ranged from 6.6 to 20.8% and the mean of all the genotypes was 11.6% (Table 1). The genotypes of *M. bombycis* had a slightly higher sugar content than those of *M. alba* and *M. latifolia* (Fig. 4). Fig. 5 shows that the relation between the fruit quantity and sugar content was not significant. However, the 4 genotypes (Myurienoaaru, Dateakagi, Akagi and Memurasaki), which bore fruits with a high sugar content (over 17%), were classified as bearing "few" fruits. Thus, these genotypes would not be suitable for fruit production in spite of their high sugar content. In contrast, Itouwase and Obawase produced fruits with a lower sugar content, but in greater quantity, and with a few leaves on them, which may account for the lower sugar content of these genotypes.

The taste test on 10 genotypes screened based on the

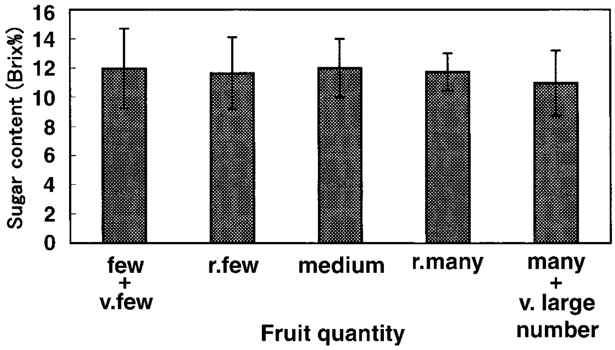


Fig. 5. Relation between fruit quantity and sugar content in mulberry

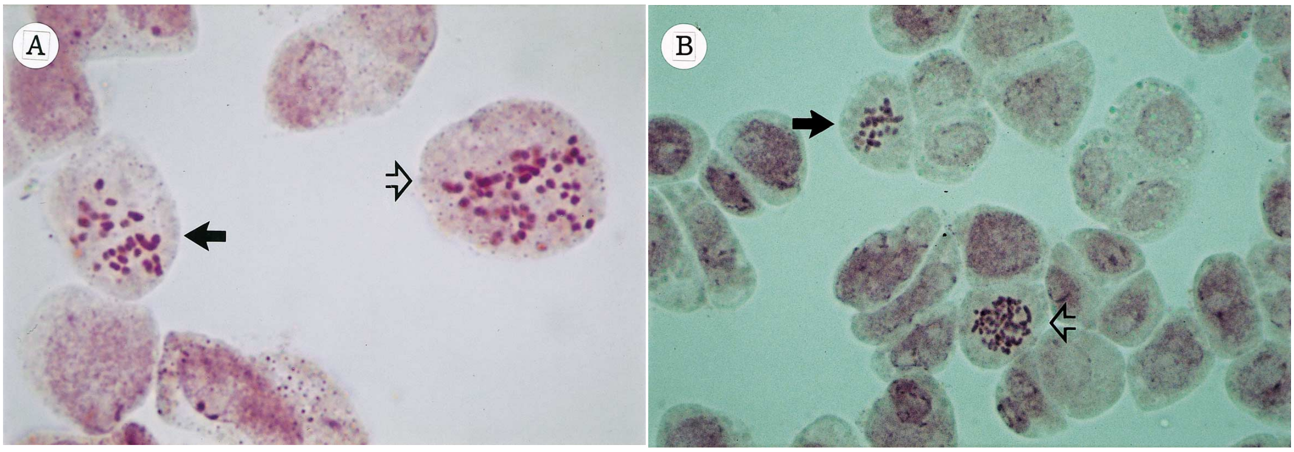
v. few (very few): almost no fruit borne per shoot,
few: approximately 5 to 10 fruits borne per shoot,
r. few (relatively few): approximately 10 to 20 fruits borne per shoot,
medium: approximately 20 to 40 fruits borne per shoot,
r. many (relatively many): approximately 40 to 60 fruits borne per shoot,
many: approximately 60 to 100 fruits borne per shoot,
v. large number (very large number): approximately more than 100 fruits borne per shoot.

fruit quantity and size showed that Okaraguwa and Kataneo were better than the other genotypes in overall evaluation (Table 2). Thus, Okaraguwa and Kataneo were selected as the genotypes suitable for fruit production from a large number of genetic mulberry resources.

2) Development of strains with large fruits

Colchicine treatment applied to the 2 genotypes, Kataneo and Okaraguwa, produced putative polyploid strains. Both of them were found to be mixoploids of diploids and tetraploids by chromosome observation (Fig. 6). In the slides, the size of the nuclei in the shoot apices was noticeably different; nuclei in the outermost cell layer were smaller than those of the inner layer. It is considered that these 2 strains were peripheral cytochimeras and that their structure was diploid-tetraploid-tetraploid-tetraploid from the outermost cell layer to the innermost one (Fig. 7). Katagiri reported that cytochimeras with the same structure as in this case were frequently induced by gamma-irradiation of growing shoots, and concluded that this type of cytochimera would be extremely stable[2]. Therefore, these 2 strains could maintain a stable chimera structure consistently.

One of the strains, FRM-01 developed from Kataneo, bore many fruits in the second year after being planted in the field. Almost all the fruit traits of this strain were the same as those of the original genotype, except that the size became larger, showing that the fruit



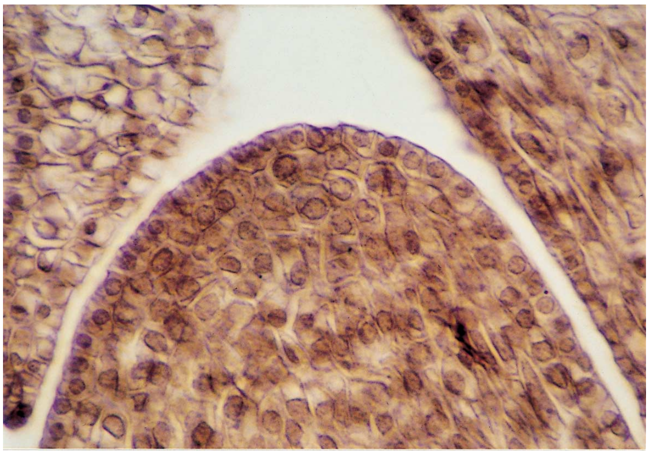


Fig. 7. Shoot apices of the strain "FRM-01"

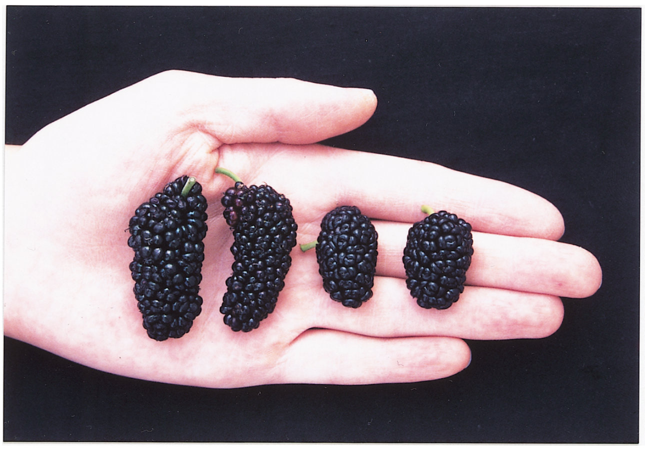


Fig. 8. Fruits of the developed strains
Right: FRM-01, Left: FRM-02.

Table 2. Taste evaluation of mulberry fruits

Genotypes	Tenmoku–yotsume	Okaraguwa	Kataneo	Nezumigaeshi	Yonbaiseisou
Appearance	6.2 ± 2.0	8.0 ± 2.3	7.8 ± 1.2	6.8 ± 1.9	4.7 ± 1.8
Sweetness	4.3 ± 1.6	6.2 ± 1.2	5.3 ± 1.6	4.5 ± 0.8	5.3 ± 0.9
Acidity	5.2 ± 1.5	5.7 ± 1.9	3.5 ± 1.7	6.5 ± 1.9	6.7 ± 1.6
Palatability	4.8 ± 0.4	5.8 ± 1.5	5.5 ± 1.0	5.3 ± 1.4	5.8 ± 1.1
Overall evaluation	4.5 ± 1.0	6.5 ± 1.0	6.3 ± 0.7	5.2 ± 0.8	5.2 ± 0.9
Genotypes	Kanadasansou A	Seisuke	Itouwase	Kenmochi	Tagowase
Appearance	7.5 ± 1.6	3.3 ± 0.9	5.8 ± 1.1	5.2 ± 0.7	4.3 ± 1.1
Sweetness	5.8 ± 1.7	4.8 ± 0.7	3.3 ± 1.8	4.5 ± 1.4	4.7 ± 1.4
Acidity	5.3 ± 2.4	4.3 ± 1.4	6.8 ± 1.5	7.0 ± 1.4	6.2 ± 1.1
Palatability	5.7 ± 1.5	4.8 ± 1.3	5.2 ± 1.6	5.2 ± 1.2	4.8 ± 0.4
Overall evaluation	5.7 ± 2.2	4.5 ± 1.0	5.0 ± 2.3	6.0 ± 0.8	5.7 ± 1.2

Table 3. Fruit traits of the mulberry strain, "FRM-01"

	Fruit Size (cm)	Fruit weight (g)	Sugar content (Brix%)	Fruit quantity (No. of fruits/plant)	Fruit yield (g/plant)
Kataneo	2.28 ± 0.32	1.94 ± 0.77	7.9 ± 1.7	389	752
FRM-01	2.65 ± 0.48	3.22 ± 1.31	8.1 ± 1.7	373	1,203

yield increased by about 60% over that of the original genotype (Table 3).

Generally, autotetraploids, such as the strains developed by colchicine treatment, show various cells and tissues with a gigantic type in mulberry[8]. FRM-01 had diploid cells at the surface, while most parts of the tissues consisted of tetraploid cells because of the chimera structure, which may explain why the fruits became larger than those of the original diploid genotypes. The other strain, FRM-02 developed from Okaraguwa, bore larger fruits than FRM-01 (Fig. 8). However, this strain became weak and bore fewer fruits in the second year. Therefore, the details on fruit traits could not be investigated.

Mulberry fruit contains several kinds of sugars, such as fructose, glucose and sucrose[6], as well as organic acids, citric acid, malic acid, etc[7,9]. The concentration of vitamin C in mulberry fruit is the same as that in Satsuma mandarin[4]. Anthocyanins have attracted the attention recently because of their antioxidative function. It is well known that mulberry fruits contain a high concentration of anthocyanins[9]. New functions of mulberry fruits other than the antioxidative activity can be investigated to promote their use as a healthy and functional food.

In the present study, several genotypes that displayed suitable traits for fruit production, such as Kataneo and Okaraguwa, were screened from a large number of genetic mulberry resources. Treatment of these 2 genotypes with colchicine enabled to develop 2 strains with larger fruits, FRM-01 and FRM-02. These strains will be released as new varieties suitable for fruit production in the near future. We hope that this study will provide useful results to further promote upland farming in Japan.

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Appendix. Inflorescence and fruit traits of 260 mulberry genotypes

No.	Genotype	Species	Inflo–rescence	Fruit quantity	Fruit length (cm)	Fruit weight (g)	Sugar content (Brix%)
1	Aikokusou	lt	♂				
2	Aizujyuujima	bm	♀♂	medium	1.6	0.66	15.0
3	Akagi	bm	♂>♀	few	1.3	0.63	17.5
4	Akajiku	bm	♂				
5	Akame Kumataka	al	♂				
6	Akamerosou	lt	♂				
7	Algeria–atsuba	lt	♀	many	–	–	–
8	Amoi 1	as	♀	many	2.0	1.40	11.1
9	Aobanezumi	al	♀	v.few	–	–	–
10	Aoichi	al	♀>♂	r.many	1.9	1.04	11.3
11	Aokirosou	lt	♀	v.few	–	–	–
12	Aoshoudo	lt	♀	few	2.1	1.26	7.7
13	Aotago	al	♂				
14	Asayuki	bm	♀	many	1.7	0.88	13.5
15	Atsubamidori	lt	♂				
16	Awamiyasou	bm	♀	few	1.4	0.44	13.7
17	Beikoku 13	mc	♀>♂	r.many	2.6	2.72	9.9
18	Bekkouguwa	lt	♂				
19	Benikawa rosou	lt	♂				
20	Chijimiguwa	bm	♀	few	1.8	1.02	–
21	Chikubayasou	bm	unknown				
22	Chiyozuru	bm	♀♂	medium	1.9	1.32	10.4
23	Chounosou	lt	♀	few	1.6	0.70	10.8
24	Chousa	lt	♀	r.many	2.4	2.17	11.1
25	Chousen zairaishu	al	♀	medium	1.6	0.95	14.1
26	Daikokusou	lt	♂>♀	no	–	–	–
27	Daishuukaku	lt	♀		2.4	1.89	10.9
28	Dateakagi	bm	♂>♀	few	1.5	0.85	18.1
29	Ebisuguwa	bm	♂				
30	Enshuu takasuke	bm	♀	many	1.1	0.30	–
31	Fukayuki	bm	♀	few	1.6	0.37	–
32	Fukushima oha	al	♀>♂	few	–	–	–
33	Fukushima wase	al	♀>♂	few	–	–	–
34	Fusoumaru	lt	♀	medium	2.3	1.33	13.2
35	Fuyousou(tomi)	bm	♀	many	1.7	0.87	14.2
36	Garyuu	lt	♀	no	–	–	–
37	Ginbashou	lt	♀	few	2.0	1.24	9.9
38	Gobou	bm	♂>♀	no	–	–	–
39	Goroujiwase	bm	♀	medium	1.1	0.41	15.5
40	Goshoerami	lt	♀	many	2.5	1.65	10.2
41	Gunmaakagi	bm	♂>♀	medium	1.4	0.63	–
42	Gunmaoha	bm	♂				
43	Hachijouguwa	kg	♀	r.few	1.6	0.56	12.0
44	Hamakawa wase	al	♀	medium	2.3	1.19	11.6
45	Hayatesakari	al	♂				
46	Hekikaioha	lt	♂>♀	few	–	–	–
47	Hidaguwa	bm	♀>♂	few	1.2	0.44	–
48	Higashitani	bm	♀	r.few	1.6	0.65	12.1
49	Hikojirou	al	♂>♀	few	–	–	–
50	Hiroeguwa	al	♀	r.many	2.5	1.40	11.4
51	Hiromaru	bm	♀	r.many	2.3	1.82	12.4
52	Hironiwase	lt	♀	few	1.8	0.99	–
53	Hojumaru	bm	♂>♀	no	–	–	–
54	Homare	lt	♀	few	1.9	1.10	11.7
55	Hosoe	al	♀	medium	2.2	1.57	12.7
56	Ichibei	bm	♀	few	1.9	0.99	12.8
57	Ichinose	al	♀	medium	2.0	1.51	10.4
58	Ichinose(akagi)	al	♀♂	many	2.2	1.43	11.1
59	Iiyama 1	al	♀	many	2.0	1.39	9.9
60	Inaguwa	al	♂>♀	v.few	–	–	–
61	Isebudou	bm	♀	medium	1.3	0.56	9.8
62	Isemaguwa	bm	♀	many	–	–	–
63	Isen K	lt	♂>♀	no	–	–	–
64	Itouwase(fuji)	bm	♀	v.large number	2.8	2.77	6.6
65	Itouwase(higashi)	bm	♂				
66	Iwase	bm	♀>♂	few	2.1	1.10	10.8
67	Jikunashi	al	♀	medium	1.7	0.72	14.4
68	Jinba	bm	♀	r.many	1.8	0.95	12.1
69	Jinguwa	lt	♂				
70	Jinza	lt	♀	medium	2.3	1.40	12.0
71	Jousen	lt	♀	many	2.6	2.32	10.8
72	Juumonji	al	♂				
73	Kairyou akame rosou	lt	♀	no	–	–	–
74	Kairyou akita	lt	♀	v.few	1.2	1.48	10.0
75	Kairyou ichinose	al	♀	r.few	2.0	1.37	13.2
76	Kairyou nezumigaeshi	al	♂>♀	medium	2.0	1.34	10.8
77	Kairyou nezumigaeshi(maruha)	al	♂>♀	r.few	2.1	1.29	11.0
78	Kairyou rosou	lt	♀	r.few	1.8	1.19	10.1
79	Kairyou ruu	lt	♀	few	2.2	1.66	10.2
80	Kairyou tsuruta	bm	♂>♀	no	–	–	–
81	Kairyou wase juumonji	al	♀	r.many	2.3	1.66	10.0
82	Kanadasansou–A	lt	♀	many	2.9	2.94	8.1
83	Kanadasansou–B	lt	♀	many	3.6	4.56	9.4
84	Kanashou	lt	♀	many	2.7	2.56	11.8
85	Kaneko	bm	♂>♀	few	–	–	–
86	Kaneko(ayabe)	bm	♂>♀	few	–	–	–
87	Kaneko(maebashi)	bm	♂>♀	few	–	–	–
88	Kaneko(matsumoto)	bm	♂>♀	few	1.7	0.63	13.2
89	Kankou 3	lt	♀	medium	2.1	1.52	8.1
90	Kanmasari	bm	♀	r.few	2.0	0.88	9.5
91	Kanrasou	lt	♂>♀	v.few	–	–	–
92	Kanton II kou	at	♀	many	2.6	3.34	7.5
93	Kasasagisou	al	♀	medium	1.8	0.81	13.1
94	Kasou	lt	♂>♀	v.few	–	–	–
95	Kasuga	lt	♀	r.few	2.3	1.76	16.2
96	Kasuga(aka)	lt	♀	medium	2.2	1.43	15.3
97	Kasuga(kuro)	lt	♀	few	–	–	–
98	Kataneo	al	♀	many	2.8	3.32	6.7
99	Kawamurarosou	lt	♂				
100	Keguwa	tf	♂				
101	Keikansou	lt	♂				
102	Keisou	lt	♂				
103	Kenmochi	bm	♀	r.many	2.3	1.43	11.5
104	Kibajuumonji	al	♂				
105	Kinsou	al	♀	medium	2.0	1.07	11.6
106	Kireha	bm	♀	r.few	1.4	0.78	12.2
107	Kobuchizawa 1	al	♀	medium	1.7	0.77	11.7
108	Kogane	lt	♀	many	1.8	1.02	10.9
109	Kokka	lt	♀	medium	2.2	1.75	12.0
110	Kokusou 13	lt	♀	r.many	1.8	1.12	13.2
111	Kokusou 20	lt	♀	medium	2.5	1.80	15.3
112	Kokusou 21	lt	♂				
113	Kokusou 27	al	♂>♀	few	1.8	0.97	11.5
114	Kokusou 70	lt	♂>♀	medium	2.2	1.45	12.3
115	Koshiorihime	bm	♀	many	2.1	1.03	11.6
116	Koukokusou	lt	♀	many	2.8	2.53	12.3
117	Kousen	lt	♀♂	r.few	1.9	0.92	10.2
118	Kousyuu 1	lt	♀	medium	2.0	1.39	9.3
119	Koutaku ginryuu	lt	♀	r.few	1.8	0.92	9.2
120	Kozaemon(fukushima)	bm	♀	many	2.8	2.30	15.1
121	Kumagayasou	al	♀	few	–	–	–
122	Kumonryuu	lt	♀>♂	medium	–	–	–
123	Kurimoto	lt	♂>♀	few	1.6	0.54	10.4
124	Kurodougi	al	♂				
125	Kuromeyamato	al	♀	many	1.8	0.97	12.5
126	Kyoukoku	lt	♂>♀	v.few	–	–	–
127	Kyuukyokusou	lt	♀	medium	2.4	1.37	11.0
128	Large	lt	♀	few	–	–	–
129	Maebashiguwa	lt	♀	r.few	2.5	1.93	12.4
130	Maruhawase	al	♀	few	1.4	0.65	9.3
131	Mayamaoha	bm	♀>♂	few	–	–	–
132	Memurasaki	bm	♀	r.few	1.1	0.34	17.1
133	Midareguwa	bm	♀♂	few	2.4	1.23	9.4
134	Mikawanakashima	bm	♀>♂	v.few	–	–	–
135	Mikunisou	lt	♀	few	2.4	1.79	10.8
136	Minamisakari	al	♂>♀	few	2.2	1.19	10.8
137	Miran 4	lt	♀	no	–	–	–
138	Miran 5	lt	♀	many	2.7	2.33	8.9
139	Mizusawaguwa	bm	♀	r.few	1.7	0.76	11.4
140	Murasakiwase	bm	♀>♂	v.few	1.4	0.48	12.8

Appendix Continued

No.	Genotype	Species	Inflo–rescence	Fruit quantity	Fruit length (cm)	Fruit weight (g)	Sugar content (Brix%)
141	Myurienoaaru	lt	♀	few	1.5	0.94	20.8
142	Naganuma	lt	♀	many	2.3	1.33	10.5
143	Nakazawa	bm	♀	r.few	1.9	1.26	8.6
144	Negoya takasuke	bm	♂				
145	Nezumigaeshi	al	♀	many	2.0	1.29	10.1
146	Nuregarasu	bm	♂				
147	Obata	bm	♀♂	r.many	1.7	0.71	10.7
148	Obawase	al	♀	many	2.4	2.63	6.6
149	Ochii	lt	♂				
150	Ohiromaru	lt	♀	few	2.1	0.92	–
151	Okaraguwa	lt	♀>♂	many	4.9	7.15	10.8
152	Okudawase	lt	♀	few	1.8	0.90	10.7
153	Okuteshirokawa rosou	lt	♀	medium	2.3	1.46	8.7
154	Oniwase	bm	♀	many	2.2	1.62	11.8
155	Onnakunitomi	bm	♀	medium	0.9	0.17	–
156	Oshimasou	lt	♂>♀	few	2.3	1.58	12.7
157	Otsukairyou rosou	lt	♀	r.few	2.0	1.24	7.9
158	Oushuuguwa	bm	♂>♀	medium	2.0	0.81	12.9
159	Owari takasuke	bm	♂>♀	v.few	–	–	–
160	Owase	bm	♂				
161	Ozekijuumonji	lt	♀	few	1.9	1.27	13.1
162	Philippine	lt	♀	r.many	2.2	1.69	12.0
163	Pionerskij	nt	♂>♀	no	–	–	–
164	Risou	al	♀	medium	1.6	0.63	11.7
165	Risuke	bm	♂>♀	few	–	–	–
166	Rohachi	lt	♀	v.few	1.0	0.33	–
167	Rokokuyasou	lt	♀	few	1.5	1.06	11.9
168	Rokunojou	bm	♂>♀	medium	1.9	0.99	11.3
169	Rosou	lt	♀♂	no	–	–	–
170	Ruinashi	bm	♀	r.many	2.3	1.69	13.0
171	Ryoumenguwa	al	♀	no	–	–	–
172	Ryuusenshuuu	al	♀	r.few	1.4	0.67	13.3
173	Sagamiwase	bm	♂>♀	v.few	–	–	–
174	Sagore	bm	♀	medium	1.1	0.45	–
175	Sakon	lt	♀♂	no	–	–	–
176	Sanoguwa	bm	♂				
177	Seijuurou	lt	♀	medium	2.2	1.48	10.5
178	Seisuke	bm	♀	many	1.6	0.63	13.7
179	Sekaiichi	lt	♂				
180	Sekizaisou	al	♀	many	1.8	1.08	13.0
181	Senmatsu	bm	unknown				
182	Shidareguwa	al	♀	few	1.2	0.62	11.5
183	Shikokkou	lt	♀♂	no	–	–	–
184	Shimanouchi	bm	♂				
185	Shimoshirazu	lt	♀	v.few	–	–	–
186	Shin ichinose	al	♂				
187	Shinjiro	al	♀	many	2.0	1.22	9.1
188	Shinkenmochi	bm	♀	medium	2.0	1.42	11.2
189	Shinkoku yasou	lt	♂				
190	Shinshironishiki	lt	♀	few	2.0	0.71	9.7
191	Shinsou 1	bm	♀	many	1.8	0.83	12.4
192	Shinsou 2	bm	♀	medium	1.6	0.77	12.8
193	Shinzanishiki	al	♀♂	v.few	–	–	–
194	Shiratama	al	♀	r.many	2.4	1.58	10.9
195	Shirokawa keisou	lt	♀>♂	few	2.3	1.14	–
196	Shirome keisou(mesu)	lt	♀	many	2.7	3.49	8.9
197	Shirome keisou(osu)	lt	♂				
198	Shirome kokkou	lt	♀	r.few	2.0	1.36	12.3
199	Shirome kumataka	lt	♂				
200	Shirome rosou	lt	♂>♀	v.few	–	–	–

No.	Genotype	Species	Inflo–rescence	Fruit quantity	Fruit length (cm)	Fruit weight (g)	Sugar content (Brix%)
201	Shironezumigaeshi	al	♀	many	1.9	1.13	11.0
202	Shiroshita	bm	♂>♀	medium	1.7	0.70	13.6
203	Shiwasuguwa	as	♀	no	–	–	–
204	Shizensei rosou	lt	♀	v.many	2.7	2.87	8.0
205	Shouji	lt	♂>♀	v.few	–	–	–
206	Shounaiwase	bm	♂				
207	Shouwasou	bm	♂				
208	Shuukakuichi	al	♂>♀	v.few	1.7	0.79	13.6
209	Siam	rt	♀	no	–	–	–
210	Sodefuri	bm	♀	no	–	–	–
211	Soshuu 1	lt	♂>♀	no	–	–	–
212	Sousukewase	bm	♀>♂	r.many	1.3	0.34	15.0
213	Souzanguwa	lt	♀	no	–	–	–
214	Sugudate	bm	♀>♂	many	2.0	0.98	14.6
215	Suigen oha	al	♀	medium	2.4	2.08	13.3
216	Surk–tut	nt	♀	v.few	–	–	–
217	Suzuren	lt	♂				
218	Tachibanasou	bm	♂>♀	no	–	–	–
219	Tadjikskaja	nt	♀	v.few	–	–	–
220	Tagowase	al	♀	many	2.1	1.14	11.1
221	Taishoutago	lt	♀	r.many	2.0	1.04	12.0
222	Taisou 35–600	lt	♂>♀	few	–	–	–
223	Takakura	bm	♂				
224	Takaoguwa	bm	♂>♀	medium	2.1	1.07	9.4
225	Takeda juumonji	al	♂>♀	few	1.8	0.99	–
226	Takinokawa	Bm	♂>♀	no	–	–	–
227	Ｔanakaoushuu	bm	♂				
228	Tengu	lt	♀>♂	medium	2.4	1.53	12.4
229	Teｎmoku yotsume	al	♀	v.many	2.0	1.40	10.8
230	Tobawase	bm	♂>♀	v.few	–	–	–
231	Tokiyutaka	al	♀	few	1.8	1.16	9.8
232	Tomieisou	al	♀	v.few	–	–	–
233	Tosawase	at	♂>♀	many	2.2	1.91	13.4
234	Tottori 2	lt	♂>♀	r.few	2.6	1.80	13.4
235	Tougounishiki	lt	♀♂	few	1.9	1.06	12.9
236	Tousou 2	lt	♀>♂	medium	2.5	2.06	11.5
237	Tousuke	bm	♂>♀	few	1.3	0.54	12.5
238	Toyokumi	lt	♀	r.many	2.3	1.63	11.3
239	Tsukasaguwa	lt	♂				
240	Tsurugisansou	lt	♂				
241	Tsuruguwa	bm	♀	few	–	–	–
242	Tsuruta	al	♀	r.few	1.5	0.46	11.7
243	Tsushima yamaguwa	bm	♀	many	2.5	2.49	11.9
244	Unryuu	lt	♂				
245	Uzbekskaja	ng	♂				
246	Wasemidori	lt	♀	v.few	1.5	0.36	–
247	Yadome	bm	♀♂	v.few	–	–	–
248	Yaei	lt	♀	many	2.3	1.61	11.0
249	Yamaguchi wase shirou	bm	♂				
250	Yamatowase	bm	♀♂	few	2.3	1.83	14.0
251	Yanagida	bm	♀♂	v.few	–	–	–
252	Yanagiha	bm	♀	many	1.8	1.12	15.1
253	Yatsubusa	al	♂				
254	Yonbaiseisou	bm	♀	many	3.0	3.25	11.0
255	Yousou	lt	♀♂	r.few	2.0	1.24	7.2
256	Yukishinogi	bm	♂>♀	no	–	–	–
257	Yukishirazu	bm	♀	medium	1.7	0.73	14.7
258	Zengasou	al	♂>♀	medium	1.7	0.80	8.5
259	Zenzou	bm	♀	many	2.1	1.92	11.4
260	Zimostojkij	lt	♀	few	1.6	0.62	10.3

Legend:
Species: al: *Morus alba* L., bm: *M. bombycis* Koidz., lt: *M. latifolia* Poir, tf: *M. tiliaefolia* Makino, as: *M. acidosa* Griff., at: *M. atropurpurea* Roxb., kg: *M. kagayamae* koidz., mc: *M. microphylla* Buckl., ng: *M. nigriformis* Koidz., nt: *M. notabilis* C.K.Schn., rt: *M. rotunbiloba* Koidz.,
Inflorescence: ♂ : staminate, ♂>♀ : predominantly staminate. ♀♂ : hermaphrodite, ♀>♂ : predominantly pistillate, ♀ : pistillate,
Fruit quantity: see Fig.5.