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Studies on Utilization of Mulberry Cultivars Introduced from Southeast and South Asia in the Breeding Program of Japanese Mulberry

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Abstract

Seedlings of the F1 plants derived from the crosses of Japanese mulberries with Thai and Indian (Kashmir's) mulberries were subjected to comparison to the cross within Japanese cultivars regarding shoot sprouting, shoot growth, rooting ability and nutrient value for feeding silkworms. The F1 seedlings of the crosses between Thai or Indian mulberries and Japanese cultivars were superior in all these characters to the cross within the Japanese materials. This result indicates that genetic improvements could be achieved by transmitting such superiority of Thai and Indian cultivars to Japanese mulberries.

Discipline: Sericulture
Additional key words: Morus alba L., Morus latifolia Poir., Morus lavigata Wall., Morus rotundiloba Koidz., nutrient value

Mulberry cultivars or strains had been introduced to Japan from various countries, including China, France, Italy, Korea, Mongolia, the Philippines, the Soviet Union, Thailand and USA during the period 1870's to 1960's (Ogure, 1967), and afterwards, from Algeria, Brazil, Canada, India, Iran, Iraq, Lebanon, Pakistan, Paraguay and Turky. These mulberry materials are now preserved by the National Institute of Sericultural and Entomological Science in Tsukuba, Japan and expected to be utilized in the breeding program in future, since they may genetically possess useful potentials in terms of growing habitude and leaf quality. Some of the materials which were introduced a few decades ago from Thailand and Kashmir district of India are recognized to be useful for their agronomic traits such as early sprouting, vigorous shoot growth, high rooting ability, and high nutrient value of leaves for feeding silkworms, *Bombyx mori*. The present paper contains some results of the genetic studies pertaining to these traits, the experiments of which have been conducted in Japan in recent years[4].

Progenies of the crosses between Thai and Japanese mulberries

Sixteen Thai mulberry cultivars *Morus rotundiloba* Koidz.[3], which possess useful agronomic characters such as early sprouting, vigorus shoot development[5] and a high rooting ability[6] were crossed with a Japanese mulberry cultivar Ichinose, *Morus alba* L. as a female, or Kokuso No. 21, *Morus latifolia* Poir., as a male. No cross incompatibility took place in all the crossings, where seed setting and germination in the crosses of Thai × Japanese cultivars (TJ-crosses) were over 50%, which is equal to the rate in the cross between Japanese cultivars.

Seedlings of one-year old grown in a greenhouse were transplanted in the field and the shoots were cut back approximately 30 cm high above the ground. The shoots developed on the trunk were cut back to the base of them before sprouting every spring. Measurements of several traits relating to shoots and leaves were recorded in the third year after transplanting.

The F_1 seedlings from the TJ-crosses generally

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Table 1. Distribution of length of the primary shoots in the F_1 seedlings derived from the crosses of Thai × Japanese mulberry cultivars*

Cross	No. of plants	Shoot length (cm)											
		Average	Distribution										
			–160	161–180	181–200	201–220	221–240	241–260	261–280	281–300	301–320	321–340	341–
Ichinose × Bai Poe	35	241		1		5	9	6	5				
Ichinose × Daeng	28	217		1	6	8	5	2					
Ichinose × Jark	28	228			2	8	8	6	4				
Ichinose × Noi	32	247			1	3	7	9	7	3	2		
Ichinose × Plong	33	259			1	1	6	6	12	5	2		
Ichinose × Soi	32	251			1	1	5	13	8	4			
Ichinose × Tadam	26	235			2	2	8	9	5				
Ichinose × Tark	34	229				12	10	7	4	1			
Ichinose × Yuak	28	201	3	3	6	8	6	2					
Keaw Stouk × Kokuso No.21	33	257		1		2	5	8	5	10	2		
Keekai × Kokuso No.21	31	254		1		2	4	7	11	5	1		
Pai × Kokuso No.21	30	270				2	3	2	10	10	1	1	1
Poo × Kokuso No.21	24	255			1	3	2	5	8	5			
Som × Kokuso No.21	30	283					1	5	5	7	11	1	
Som Yai × Kokuso No.21	24	235	1		2	5	6	3	5	1	1		
Tonkin × Kokuso No.21	32	223		1	4	7	9	10	1				
Ichinose × Kokuso No.21	30	206		2	10	8	7	3					

* Measurements were taken in the third year after transplanting.

grew more vigorously as compared with those from the cross between Japanese cultivars (JC–cross). The longest shoot among the primary shoots of the F_1 seedlings from the TJ–crosses was about 20% greater than that from the JC–cross on an average (Table 1). The longest shoot among the plants from the cross of Pai × Kokuso No. 21 was 370 cm, while that from the cross of Ichinose × Kokuso No. 21 was 260 cm, or approximately 70% of the former. Less shoots developed on the trunks of the F_1 seedlings from the TJ–crosses as compared with those from the JC–cross with a few exceptions where some of the former crosses segregated plants which had the same number of shoots with the latter cross. Regarding the secondary shoots on the primary shoots of the F_1 seedlings, more shoots developed in the TJ–crosses as compared with those in the JC–cross (Table 2). An average of 50% of the primary shoots did not develop any secondary shoots in the F_1 seedlings of the cross of Japanese cultivars, whereas approximately 15% only did not develop them in the TJ–crosses.

Table 2. Distribution of number of the secondary shoots in the F_1 seedlings derived from the crosses of Thai × Japanese mulberry cultivars*

Cross	No. of plants	Number of secondary shoots												
		Average	Distribution											
			0	1–2	3–4	5–6	7–8	9–10	11–12	13–14	15–16	17–18	19–20	21–
Ichinose × Bai Poe	35	5.8	3	6	6	6	5	3	3	3				
Ichinose × Daeng	28	6.1	2	7	5	3	1	5	1	2	1	1		
Ichinose × Jark	28	3.1	5	9	5	4	5							
Ichinose × Noi	32	3.9	7	6	6	8	1	3		1				
Ichinose × Plong	33	11.8	1	1	5	1	2	5	4	4	2	3	1	4
Ichinose × Soi	32	8.2	2	3	2	6	5	6	4		1		3	
Ichinose × Tadam	26	8.2	2	1	4	4	3	5	2	3		1	1	
Ichinose × Tark	34	5.1	1	6	12	9	1	1	2	1		1		
Ichinose × Yuak	28	5.2	4	4	6	4	3	5	1		1			
Keaw Stouk × Kokuso No.21	33	2.2	11	9	10	2				1				
Keekai × Kokuso No.21	31	4.6	4	5	9	6	3	2		1		1		
Pai × Kokuso No.21	30	5.1	5	7	4	6	2	2	2	1				1
Poo × Kokuso No.21	24	7.9	4		6	2	1	4	1	3	1			2
Som × Kokuso No.21	30	3.6	9	5	6	5	1	2	1		1			
Som Yai × Kokuso No.21	24	4.2	4	5	8	1	4	1						1
Tonkin × Kokuso No.21	32	2.7	17	3	4	3	1	2	1	1				
Ichinose × Kokuso No.21	30	1.6	15	8	4	1	2							

* Measurements were taken in the third year after transplanting.

Leaf size of the F_1 seedlings from the TJ–crosses varied, depending on their parents. The F_1 seedlings derived from the crossings with Kokuso No. 21, a large-leaf variety beared large leaves as compared with those from Ichinose, a medium size-leaf variety. Segregations of leaf shape in the F_1 seedlings also varied, depending on their parents. A majority of the crosses of 5–lobed leaf × 5–lobed leaf and 5–lobed leaf × entired leaf both produced plants bearing leaves in a range of entired to 7–lobed leaves. However, the cross of Ichinose × Yuak produced plants bearing entired to multi-lobed leaves, while the crosses of the varieties which bear multi-lobed leaves produced plants of entired to multi-lobed leaves (Table 3). Katsumata[2] reported that in the cross of *Morus kagayamae* Koidz. with Kairyou-nezumigaeshi, *Morus alba* L., the multi-lobed leaf type was genetically dominant to the 5–lobed leaf type. In the present study, however, the cross of Ichinose, a 5–lobed type × Plong, a multi-lobed leaf type, derived approximately 50% of the F_1 seedlings

Table 3. Distribution of leaf shape in the F_1 seedlings derived from the crosses of Thai × Japanese mulberry cultivars*

Cross	No. of plants	Leaf shape					Leaf shape of parent
		Entired	3-lobed	5-lobed	7-lobed	multi-lobed	
Ichinose × Bai Poe	34	20	3	11			5-lobed × 5-lobed
Ichinose × Daeng	26	12	10	4			5-lobed × 5-lobed
Ichinose × Jark	26	9	7	10			5-lobed × 5-lobed
Ichinose × Noi	32	10	9	13			5-lobed × 5-lobed
Ichinose × Plong	33	8	4	15	4	2	5-lobed × multi-lobed
Ichinose × Soi	32	20	7	5			5-lobed × 5-lobed
Ichinose × Tadam	26	10	5	10	1		5-lobed × 5-lobed
Ichinose × Tark	33	24	4	5			5-lobed × 5-lobed
Ichinose × Yuak	28	7	6	13		2	5-lobed × 5-lobed
Keaw Stouk × Kokuso No.21	31	22	6	1	2		5-lobed × entired
Keekai × Kokuso No.21	33	24	8	1			5-lobed × entired
Pai × Kokuso No.21	30	6	5	17	1	1	multi-lobed × entired
Poo × Kokuso No.21	27	20	5	2			5-lobed × entired
Som × Kokuso No.21	30	2	5	15	6	2	multi-lobed × entired
Som Yai × Kokuso No.21	25	1	4	13	5	2	multi-lobed × entired
Tonkin × Kokuso No.21	32	24	6	2			5-lobed × entired
Ichinose × Kokuso No.21	30	15	3	11	1		5-lobed × entired

* Measurements were taken in the third year after transplanting.

bearing 5-lobed leaves. In order to identify a gene constitution pertaining to leaf-shape, further studies are required.

Rooting abilities of seven plants randomly selected in each of TJ- and JC-crosses were tested on the basis of one-year-old shoots sampled before sprouting. The F_1 seedlings from the TJ-crosses generally expressed higher rooting abilities than those from the JC-cross; a mjority of the former crosses produced roots by 100% or so, whereas the JC-cross did by only less than 50% (Table 4).

In the third year after transplanting, sprouting dates of buds were subjected to investigation on the basis of one-year-old shoots. The buds on the F_1 seedlings from the TJ-crosses sprouted about a week earlier than those from the JC-cross.

From the above results obtained in the study on TJ-crosses, it may be concluded that agronomically useful characters such as early sprouting, vigorous shoot growth and high rooting ability of the Thai mulberries can be transmissible into seedlings of Japanese mulberries.

Table 4. Rooting ability in the F_1 seedlings derived from the crosses of Thai × Japanese mulberry cultivars*

Cross	No. of cuttings	No. of rooted cuttings	% of rooted cuttings
Ichinose × Bai Poe	20	20	100
Ichinose × Daeng	21	21	100
Ichinose × Jark	21	21	100
Ichinose × Noi	21	20	95.2
Ichinose × Plong	21	21	100
Ichinose × Soi	21	20	95.2
Ichinose × Tadam	21	17	80.9
Ichinose × Tark	21	15	71.4
Ichinose × Yuak	21	12	57.1
Keaw Stouk × Kokuso No.21	21	18	85.7
Keekai × Kokuso No.21	21	20	95.2
Pai × Kokuso No.21	21	19	90.4
Poo × Kokuso No.21	21	14	66.6
Som × Kokuso No.21	21	19	90.4
Som Yai × Kokuso No.21	21	17	80.9
Tonkin × Kokuso No.21	21	12	57.1
Ichinose × Kokuso No.21	21	9	42.8

* Cuttings were sampled from 7 plants and 3 cuttings per plant.

Table 5. Distribution of total shoot length in the F_1 seedlings derived from the crosses of Indian mulberry strains and Japanese mulberry cultivars*

Cross	No. of plants	Shoot length (cm)											
		Average	Distribution										
			−250	251−500	501−750	751−1000	1001−1250	1251−1500	1501−1750	1751−2000	2001−2250	2251−2500	2501−
Ichinose × Kashmir-13	99	1281		2	8	23	19	16	17	8	2	3	1
Kashmir-7 × Kokuso No.21	100	1280		3	7	17	25	18	13	8	9		
Kashmir-11 × Kokuso No.21	100	1269		3	8	14	32	16	12	5	8	2	
Ichinose × Kokuso No.21	95	1032	5	4	14	19	29	14	4	1	5		

* Measurements were taken in the second year after transplanting.

Table 6. Feeding value of mulberry leaves evaluated by rasing silkworms, *Bombyx mori*, in 5th larva stage

(a) Spring raising season

Cultivar or strain	Term of 5th larva stage (h)	Cocoon weight (g)	Cocoon shell weight (cg)	Digestibility (%)	Cocoon shell production efficiency (dry %)*	Cocoon shell production efficiency (fresh %)*
Ichinose	143	3.14	66.3	39.8	10.4	2.65
Kairyourosou	144	3.05	65.4	38.7	10.3	2.62
Kashmir-7	145	3.29	74.9	40.7	12.6	2.98

(b) Late autumn raising season

Cultivar or strain	Term of 5th larva stage (h)	Cocoon weight (g)	Cocoon shell weight (cg)	Digestibility (%)	Cocoon shell production efficiency (dry %)*	Cocoon shell production efficiency (fresh %)*
Ichinose	163	2.25	53.2	31.3	9.26	2.83
Kairyourosou	168	2.15	51.5	29.5	9.11	2.56
Kashmir-7	163	2.48	58.1	33.1	9.67	2.98

* Cocoon shell production efficiency = Cocoon shell weight / Ingested mulberry leaf weight (dry or fresh) × 100

Progenies of the crosses between Indian (Kashmir's) and Japanese mulberries

Three Indian mulberry strains, *Morus lavigata* Wall.[3], were crossed with Japanese mulberry cultivars Ichinose as a female, or Kokuso No. 21 as a male. The Indian materials have useful traits such as vigorous shoot growth and high nutrient value of leaves for feeding silkworms. Cross incompatibility was not associated with the crosses of Indian strains × Japanese cultivars (IJ-crosses). Seed setting and germination was of over 50% in the IJ-crosses, which was the same level with the JC-cross.

Following the same procedure with the case of TJ-crosses, the IJ-crosses were tested regard to their shoot development, leaf size and shape. The leaves of the F_1 plants were evaluated with their nutrient value.

The F_1 seedlings of the IJ-crosses showed more vigorous growth than the materials of JC-cross: the total shoot-length of the F_1 seedlings from the IJ-crosses was greater than the JC-cross by 10% (Table 5). Among the IJ-crosses, the hybrid of Ichinose × Kashmir-13 produced more plants which indicated a greater total shoot-length. However, as far as the number of primary shoots and secondary shoots were concerned, no significant differences were found among the IJ-crosses.

Size of the leaves of the F_1 seedlings of the IJ-crosses was smaller than that of the JC-cross, reflecting the cause that the three Indian parents were smaller in leaf size than the two Japanese parents. The shape of leaves developed on the primary shoots in the IJ-cross F_1's was in a range of entired to 7-lobed, while the leaf shape of the two Indian parents, Kashmir-7 and -13, was entired and another Indian parent, Kashmir-11, was of 5-lobed leaves.

Nutrient value of leaves of the following materials was analyzed: Indian strain Kashmir-7, Japanese cultivars Ichinose and Kairyourosou, *Morus latifolia* Poir., which is the same species with Kokuso No. 21. The nutrient values were tested by raising silkworms both in the spring and autumn seasons. Feeding value of the Indian strain was superior to that of the Japanese cultivars, as indicated in cocoon weight, cocoon shell weight, digestibility and cocoon shell production efficiency (i.e. cocoon shell weight/ingested mulberry leaf weight × 100) (Table 6).

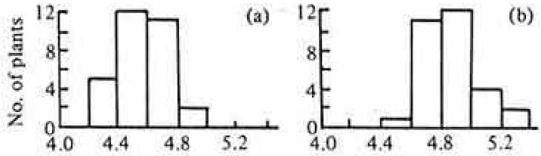

Fig. 1. Distributions of nitrogen contents in leaves of the F_1 seedlings derived from the crosses of Indian mulberry strain Kashmir-7 × Japanese mulberry cultivar Kokuso No. 21

Taking into consideration that the cocoon shell production efficiency is positively correlated in general with the nitrogen content of leaves[1], contents of nitrogen were also compared among the leaves of 30 seedlings randomly sampled in the two F_1 crosses: Kashmir-7 × Kokuso No. 21 and Ichinose × Kokuso No. 21. Distributions of the nitrogen contents in leaves differed in the two crosses: the former produced more seedlings bearing leaves with higher nitrogen content as compared with the latter (Fig. 1).

In summary, the IJ-crosses indicated a greater vigor of shoot growth and a higher feeding value of leaves than the JC-cross. This result suggests that useful germplasms of Indian strains be transmissible into Japanese mulberries.

References

1) Katagiri, K. & Machii, H. (1988): Varietal differences of value of leaves as food of silkworm, *Bombyx mori*, in mulberry. *Tech. Bull. Sericul. Exp. Sta.*, **134**, 119–128 [In Japanese].
2) Katsumata, F. (1982): Inheritance of some of the traits in an interspecific hybrid between *Morus kagayamae* Koidz. and Kairyounezumigaeshi (a form of *Morus alba* L.). *J. Sericul. Sci. Jpn.*, **51**, 381–388.
3) Koidzumi, G. (1917): For the genus *Morus* — taxonomy and distribution —. *Bull. Sericul. Exp. Sta.*, **3**, 1–62 [In Japanese].
4) Kobayashi, S. & Nakajima, K. (1988): Breeding test of Thai mulberry varieties. *Acta Sericologica*, **142**, 11–24 [In Japanese].
5) Maneechote, S. (1972): Survey on the practical characters of Thai varieties of mulberry. (2) Yield. *Bull. Thai Sericul. Res. Train. Centre.*, **2**, 17–19.

6) Ogure, M. (1967): Present status of collection of mulberry. *In* Present status of collection, introduction and conservation of seeds and seedlings in perennial crops. Agriculture, Forestry and Fisheries Research Council, 165–175 [In Japanese].

7) Yamakawa, K. & Hongthongdaeng, B. (1975): Survey on the practical characters of Thai varieties of mulberry. (10) Root initiation. *Bull. Thai Sericul. Res. Train. Centre*, 5, 19–20.

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