Similar introduction and incorporation of potato chloroplast DNA in Japan and Europe

Kazuyoshi HOSAKA

*Experimental Farm, Kobe University, 1348 Uzurano, Kasai,
Hyogo 675-21, Japan*

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ABSTRACT

The chloroplast DNA (ctDNA) type was determined for most of Japanese potato varieties including both officially registered and unregistered varieties and those of unknown origin. Many modern varieties have T type ctDNA similar to the present European potatoes. Some varieties have W type ctDNA which was derived from *S. demissum*. Most of varieties of unknown origin have T type ctDNA. It indicates those were introduced after late blight epidemics in Europe and/or bred from them. Four old varieties have A type ctDNA which is typical to Andean potatoes and has been found in a derivative of the oldest European variety, Myatt's Ashleaf. Considering the historical background in Japanese potatoes, it is suggested that these old varieties are relic potatoes of the early European potato and similar ctDNA introduction and incorporation occurred in both Europe and Japan.

1. INTRODUCTION

There are two types of native cultivated tetraploid potatoes in South America; a short-day adaptable type, *Solanum tuberosum* ssp. *andigena*, in the Andean highlands and a long-day adaptable type, ssp. *tuberosum* in the coastal Chile (Hawkes, 1956). The potato was first brought from South America to Europe in the late 16th century (Salaman, 1937; Hawkes, 1956). It was *S. tuberosum* ssp. *andigena*, based on morphological observation of old herbarium specimens maintained in Europe (Salaman and Hawkes, 1949; Hawkes, 1956). As ssp. *andigena* did not form tubers in the summer in Europe, long-day adaptable types were selected and became ssp. *tuberosum* by the mid-18th century (Hawkes, 1956) or the 19th century (Simmonds, 1964). A great turnover occurred in the 1840s. Almost all previously existing varieties were lost by late blight attack, and then, replaced by Chilean ssp. *tuberosum*, namely, cv. Rough Purple Chili and its descendants.

Chloroplast DNA (ctDNA) restriction enzyme analysis is capable of tracing the above-mentioned history (Hosaka, 1986). The A type ctDNA is predominant in northern Andean ssp. *andigena*. The T type ctDNA is of Chilean ssp. *tuberosum*. Thus, the first European potato could have A type ctDNA. This was supported by cv. Myatt's Ashleaf, the only available old European variety so far

had A type ctDNA (Hosaka and Hanneman, 1988). Cvs. Garnet Chili and Early Rose, both being immediate descendants of Rough Purple Chili, and many other modern varieties have T type ctDNA, indicating total replacement of ctDNA from A to T type (Hosaka and Hanneman, 1988). Some recent varieties, e.g. cv. Greta, have W type ctDNA which was derived from the cytoplasm of *S. demissum*, a donor of late blight resistance (Hosaka et al., 1984).

The first introduction of the potato into Japan is generally recognized to be during Keicho period (1596–1614) (Kawakami, 1948; Asama, 1978). It is believed that the Dutch brought potatoes to Nagasaki. As a result of famines, potatoes spread over the country as a hardy crop, particularly to the cooler mountain regions in the central Japan where they also avoided virus infection. For approximately two hundred years until 1854, Japan had closed to the outer world except Chinese and Dutch traders. Since mid-19th century when Japan opened its doors to the outer world, new materials were successively introduced, then modern breeding programs started in the early 20th. Until the present, approximately 40 varieties have been officially registered.

Considering the above-mentioned historical background of Japanese potatoes, it may be possible to find in Japan the descendant of the first or early European potato carrying characteristics of ssp. *andigena*. Such descendants have been found in India (Swaminathan, 1958), in Basutoland (Van der Plank, 1946), and in the Canary Islands (Zubeldia et al., 1955, in Howard, 1970).

In this study, ctDNA types of all available registered varieties and 30 varieties of unknown or ambiguous origin in Japan are determined.

2. MATERIALS AND METHODS

Plant materials used in this study are listed in Table 1 and 2. These were provided mainly from Hokkaido National Agricultural Experiment Station (Shimamatsu, Hokkaido) and partly from Nagasaki Agricultural and Forestry Experiment Station (Aino, Nagasaki), Hokkaido Prefectural Kosen Agricultural Experiment Station (Nakashibetsu, Hokkaido) and Saitama Prefectural Agriculture and Forestry Promotion Center (Chichibu, Saitama).

CtDNA restriction enzyme analysis was followed by the procedures described by Hosaka and Hanneman (1987). CtDNA types were determined based on *Bam*HI digestion patterns, as defined by Hosaka (1986).

3. RESULTS AND DISCUSSION

Modern varieties

CtDNA types of thirty-five varieties bred and released in Japan and three foreign varieties officially registered in Japan were determined (Table 1). T type ctDNA was dominant, but nine varieties had W type ctDNA. The most success-

ful foreign variety, cv. Irish Cobbler, which donated T type ctDNA to a half of the total number of varieties bred in Japan, was said to have arisen by a bud mutation from Early Rose (Salaman, 1926). Early Rose contributed to many modern

Table 1. Potato varieties officially registered in Japan and their chloroplast DNA types

Variety	Released	Female parent	Male parent	CtDNA
Irish Cobbler	introduced	Early Rose		T
May Queen	introduced	?	?	T
Tunika	introduced	Lü56.186/21N	Lü51.183/2	W
Benimaru	1938	L. F. Rosen	Pepo	T
Myojo	1938	Nemuro-murasaki	Pepo	T
Hokkaishiro	1938	Irish Cobbler	Pepo	T
Bifukashiro	1942	Irish Cobbler	Deodara	T
Bifukabeni	1942	Kamiya-imo	Pepo	T
Norin 1	1943	Irish Cobbler	Deodara	T
Norin 2	1945	Irish Cobbler	Pepo	T
Nemurobeni	1952	Honiku 393	Parnassia	T
Chitose	1953	Irish Cobbler	Honiku 393	T
Oojiro	1954	Irish Cobbler	Norin 1	T
Unzen	1955	Norin 1	Katahdin	T
Tachibana	1955	Norin 1	Katahdin	T
Yoraku	1958	41089-8	Norin 1	W
Niseko	1959	Norin 1	Mirabilis	T
Rishiri	1960	41089-8	Norin 1	W
Shimabara	1960	Norin 1	Gineke	T
Eniwa	1961	S-267	S-232	T
Yukijiro	1961	Kennebec	Norin 2	T
Chijiwa	1962	54042-15	Unzen	W
Hokkai-aka	1965	2070-ab(31)	S-290	T
Shiretoko	1967	Hokkai 24	S-291	W
Bihoro	1969	Hokkai 29	Hochprozentige	T
Tarumae	1969	Oojiro	Hochprozentige	T
Dejima	1971	Hokkai 31	Unzen	T
Waseshiro	1974	Konkei 7	Hokkai 39	T
Toyoshiro	1976	Hokkai 19	Eniwa	T
Setoyutaka	1977	Saikai 10	Unzen	W
Nishiyutaka	1978	Dejima	Choukei 65	T
Hatsufubuki	1979	Irish Cobbler	WB61037-4	T
Hokkaikogane	1981	Toyoshiro	Hokkai 51	T
Konafubuki	1981	Toyoshiro	WB66201-10	T
Toyo-akari	1986	Tunika	WB61037-4	W
Meihou	1986	Chijiwa	Choukei 80	W
Kita-akari	1987	Irish Cobbler	Tunika	T
Ezo-akari	1987	Tunika	Priekulsky Ranny	W

varieties including the most famous American variety, Russet Burbank. Thus, it is reconfirmed that T type ctDNA is major ctDNA worldwide.

Cv. Tunika and its derived cvs. Toyo-akari and Ezo-akari had W type ctDNA in common because the cytoplasm of cv. Tunika came from a so-called W-race, which was a German breeding line derived from *S. demissum* (Ross, 1986). The 41089-8, an important breeding line as a late blight resistance donor bred by the Japanese using *S. demissum*, donated W type ctDNA to Yoraku, Rishiri, Chijiwa, Setoyutaka and Meihou (Table 1). W type ctDNA was apparently inherited from

Table 2. Chloroplast DNA types of Japanese potatoes of unknown or those not officially registered

Accession	CtDNA	Note*
Bansei-danshaku-imo	T	(Late matured Irish Cobbler)
Ginzanmurasaki	T	
Higashiiya-zairai	T	(Landrace from Higashiiya), from Higashiiya, Shikoku
Higashiiya-zairai 2	T	(Landrace 2 from Higashiiya), from Higashiiya, Shikoku
Hinomaru 1	T	Early Rose × Gratiola, introduced from Saghalien
Iwate 4	T	Belgian-Hei × Nemuro-murasaki
Kamiya-imo 1	T	= Cimbal's Phœnix?, introduced from Germany
Kannan-aka	T	(Red Kannan), introduced from Korea
Kannan-jiro	T	(White Kannan), introduced from Korea in 1933
Kintoki-imo	T	(Kintoki tuber)
Kitanaraoka-zairai	T	(Landrace from Kitanaraoka)
Kobo-imo	T	(Kobo's tuber)
Furumagi	T	
Kushiro-san	T	(From Kushiro), from Kushiro, Hokkaido
Makubetsu	T	From Makubetsu, Hokkaido
Murasaki-imo	A	(Purple tuber), from Chichibu-region, Saitama
Musa	T	
Nagasaki-aka	T	(Red one from Nagasaki), from Nagasaki, Kyushu
Nagasaki-ki	T	(Yellow one from Nagasaki), from Nagasaki, Kyushu
Nagasaki-murasaki	T	(Purple one from Nagasaki), from Nagasaki, Kyushu
Nagasaki-zairai B	T	(Landrace B from Nagasaki), from Nagasaki, Kyushu
Nakarumoi	T	From Nakarumoi, Hokkaido
Nakatsugawa-imo	T	(Tuber from Nakatsugawa), from Chichibu-region, Saitama
Nemuro-murasaki	A	(Purple one from Nemuro), from Nemuro, Hokkaido
Neodelicious (or Red Andes)	T	Early Rose × <i>S. phureja</i> , bred by Dr. K. Kawakami
Rankoku 3	A	
Rankoku 5	A	
Sanyen-imo	T	= Vermont Gold Coin, imported from USA
Shikoku-zairai 1	T	(Landrace 1 from Shikoku), from Shikoku
Shirobana-danshaku-imo	T	(White-flowered Irish Cobbler)

* English translation of the cultivar name in parentheses.

S. demissum (Hosaka et al., 1984) through back-crossings of *S. demissum* (6x) by *S. tuberosum* (4x) for introduction of late blight resistance from the former species. The origin of W type ctDNA of Shiretoko is not known since the pedigree information of the grandmother of Shiretoko (HLT-4 from USA) is not available.

According to the available information, cv. Myojo was selected from hybrid progenies of Nemuro-murasaki (female)×Pepo (male). But, this seems to be a mistake because Myojo (T type ctDNA) and Nemuro-murasaki (A type ctDNA) had different ctDNA (Table 1 and 2).

Other Japanese varieties

Thirty varieties, which are of unknown origin or those not officially registered, were examined for their ctDNA types. Again, most of them had T type ctDNA. Possession of T type ctDNA in some varieties could be explained by their pedigree; for example, cv. Bansei-danshaku-imo (a sport of Irish Cobbler) and Hinomaru 1 (Early Rose×Gratiola) (Table 2). Possession of T type ctDNA suggests that these varieties were derived from Chilean ssp. *tuberosum* later than the 1840s.

Four varieties, Murasaki-imo, Rankoku 3, Rankoku 5 and Nemuro-murasaki, had A type ctDNA. The last three potatoes have been maintained at experiment stations and are not grown by farmers at present. Murasaki-imo is still locally grown for home consumption in the central Japan (Uchino, H., personal communication). The A type ctDNA is specific to ssp. *andigena* and was found in cv. Myatt's Ashleaf (more strictly to mention, a hybrid having the cytoplasm from Myatt's Ashleaf) (Hosaka and Hanneman, 1988) which is the only available potato grown in Europe before late blight epidemics of the 1840s (Salaman, 1926). Considering that there is no record of introduction of ssp. *andigena* into Japan until the 20th century, it is apparent that these Japanese potatoes descended from the early European potatoes.

It is generally recognized that the potato was introduced to Japan by the Dutch via Java (Indonesia) in Keicho period (1596–1614) (Kawakami, 1948; Asama, 1978) or in between 1609 and 1615 (Laufer, 1938). During the period of about two hundred years between 1639 and 1854, Japan was closed to the outside world except for the Chinese and Dutch who traded at Nagasaki, the only permitted trading port. Since the first introduction, the potato gradually spread via a succession of famines as a hardy crop in mountain regions or cool areas in central and northern Japan. Potatoes were introduced into Hokkaido in 1706 (Asama, 1978). Under strictly restricted conditions of transportation for farmers by governmental policies, it is amazing that potatoes reached Hokkaido from Nagasaki in about one hundred years. Based on these historical considerations, repeated introduction is accordingly less probable. Thus, it is likely that the four A type potatoes were derivatives of the first or very early potato introductions to

Japan, which in turn might be the immediate descendants of the first or very early European potato.

Another possible introduction into Japan could be from Russia (Laufer, 1938). It has been suggested based on linguistic evidence that some Ainu peoples in Hokkaido received potatoes from Russia during the Kansei period (1789–1800), but those did not spread as widely as those from Nagasaki because of low quality (Asama, 1978).

Potato evolution in Japan

In Europe, A type ctDNA was first brought and then replaced mostly by T type ctDNA. Through modern breedings, W type of *S. demissum* has been introduced into the mass of developed varieties. Similar ctDNA introduction and incorporation occurred in Japan. Four old varieties possessing A type ctDNA are proposed to be relic potatoes of the early European potato introductions. The analysis of nuclear DNA may reveal genetic relationships among these four early Japanese potatoes and Myatt's Ashleaf.

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