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UTILIZATION OF PLANT GENETIC RESOURCES FOR CROP IMPROVEMENT

TECHNICAL ASSISTANCE ACTIVITIES FOR GENETIC RESOURCES PROJECTS

JAPAN INTERNATIONAL COOPERATION AGENCY

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Introduction

The committee for technical assistance activities for genetic resources projects was initiated under the sponsorship of JICA in 1988. Since then, a series of references or manuals have been published covering a wide range of plant genetic resources as follows:

No.1, Preservation of plant genetic resources.

No.2, Exploration and collection of plant genetic resources (seed crops)

No.3, Exploration and collection of plant genetic resources (vegetatively propagated crops)

No.4, Evaluation and classification of plant genetic resources.

Now here is the last of the series, which covers utilization of plant genetic resources. Although there will be a supplemental booklet, the experiences in the area of plant genetic resources have been covered by this series. The reader may understand the sequence of topics starting from preservation and ending with utilization of plant genetic resources, as better use of plant genetic resources is an ultimate goal of the whole activities in this area.

For the past decade a great deal of progress has been made for conservation of genetic resources both in developed and developing countries. As genetic resources have their own value to be conserved at any cost, the progress is a consolatory event in the global concern for loosing genetic diversity. While collected genetic resources are conserved in costly storages, expectation is growing that the resources should be more effectively utilized for agriculture and people's welfare. For systematic evaluation and utilization of the resources, however, a certain strength of breeding programs is essential. To evaluate and utilize genetic resources which have been collected for the past decade, support for breeding programs in developing countries should be of primary importance in the coming decade.

To develop systematic utilization of genetic resources, there should be many factors to be examined; some may be related to screening technologies, and others be related to funding strategies. For a screening project to be creative, genetic diversity which may contain variation independent of adaptive value must be secured in the forms of large collection. Also, creative imagination and strong will are essential to find a new useful trait in a work of mass screening.

In this booklet, a large number of successful instances are presented. We may deduce here at least two conclusions: First, utilization of genetic resources, particularly of those exotic can be successful, if a certain strength of breeding program is attained to digest exotic forms. From this point of view, measures should be taken for effective utilization of genetic resources. Second, to obtain any significant results in evaluation of genetic resources capability for mass screening is necessary in coordination of trained manpower and medium or long term funding. Allocation of more resources than those conceived may be needed for this task in the coming decade.

Contribution of genetic resources to agriculture has been enormous in yield increase, improved resistance to disease and insect, and in quality improvement of crops and vegetables. In many cases, such progress obtained by incorporation of new genes is marvellous and beyond of initial expectation, as explained by respective papers in this booklet. The reader may get a vivid idea of how genetic resources can be exploited toward such marvellous achievements.

The contributors to this booklet are all expert breeder in respective areas. Above all, we are thankful to Dr. K. TORIYAMA for his pains taking survey of many reports including his own experiences.

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Cereals

by

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CONTENTS

1. Rice

There are two cultivated rice species, Asian cultivated rice *Oryza sativa* L. and African cultivated rice *O. glaberrima* STEUD. Of them, Asian rice is the most important crop as a staple diet for Asian peoples. Asian cultivated rices may have originated in high land areas ranging from Yunnan, the northern Thailand, the upper Myanmar (Burma) to Assam, and is classified into two subspecies, *japonica* and *indica*. As Japan is close to the border in the distribution of Asian cultivated rice, potential genetic variability is narrow for rice breeding due to convergence of genetic diversity. Japanese rice breeders, therefore, have utilized exotic germplasms to widen the genetic background.

1) Semi-dwarfism

The most important characteristics of rice is a high yielding ability, which is an integrated result of a genetic ability, environmental conditions and cultivation techniques including fertilizing. Vigorous plant growth by heavy fertilizing is a basis for high yield unless lodging occurs. But an increased culm length by heavy fertilizing often causes severe lodging and yield loss. Semi-dwarf gene, therefore, is a key trait to solve this problem under heavily fertilized soils in Japan.

A Japanese land race with short stature has been selected by local farmers in the fertile plain around Ariake Bay in Kyushu where common rice cultivars are liable to lodge without fertilizing. Whereas, the short-statured, lodging-resistant land race, 'Jukkoku', was not popular in the area because it was susceptible to common rice diseases and poor in grain quality.

Improvement of short-statured cultivars with the semi-dwarfism gene of 'Jukkoku' has been conducted for disease resistance and grain quality, and a series of new semi-dwarf cultivars,' Houyoku', 'Reihou', and others were developed at the National Kyushu Agricultural Experiment Station, and 'Nishihomare', 'Shinrei', and others were developed at Miyazaki Agricultural Experiment Station. Those newly developed semi-dwarf cultivars has successfully brought a sharp yield increase in Kyushu areas.

Utilization of the semi-dwarfism gene has also been successful in yield increase of rice in the Asian tropics under the initiative of the International Rice Research Institute (IRRI) in the Philippines. The semi-dwarfism gene, *sd-1*, of 'Dee geo woo gen' from Taiwan was introduced into 'IR 8' and its derivatives such as 'IR 26', 'IR 36', etc.. Especially, the area of 'IR 36' in the Asian tropics has reached more than ten million ha. No single crop variety has ever planted to such vast area. Dr. H. M. BEACHEL and Dr. G. S. KHUSH were awarded the 1989 Japan Prize for their outstanding work as the basis for "the Green Revolution in the Asian Tropics". The gene *sd-1* of 'Dee geo woo gen' is later confirmed to be at the same locus of the semi-dwarf gene of 'Jukkoku'.

2) Disease and insect resistance

Since early times of scientific plant breeding in Japan, introduction of resistance gene(s) against diseases and insect pests from exotic germplasms has been an essential part of plant protection. Especially, the use of resistance gene(s) is the most effective and practical way to control virus diseases, plant hoppers and leaf hoppers, which are not easily controlled by pesticides.

In the warm region of Japan, direct seeding or early transplanting of rice occasionally brought severe damage to the production due to outbreaks of stripe disease which is transmitted by smaller brown planthopper. Resistant cultivars have only been effective to control stripe disease, while chemical control of the vector insects was not much successful. Farmers, therefore, were anxious for resistant cultivars to cope with the disease. Though there was no resistant cultivars among indigenous lowland rices, highly resistant sources for stripe disease were found among Japanese upland rices and *indica* rices. Firstly, rice breeders studied the genetic system of stripe disease resistance at the National Chugoku Agricultural Experiment Station. Resistance of Japanese upland rice cultivars is found to be controlled by two pairs of dominant complementary genes, *Stv-a* and *Stv-b*, while resistance of *indica* cultivars is controlled by one pair of incomplete dominant gene, $Stv\text{-}b^i$. The first stripe disease resistant Japanese paddy rice with the $Stv\text{-}b^i$, 'St 1', was selected from offsprings backcrossed between an indica cultivar, 'Modan', as a donor and a Japanese paddy rice cultivar, 'Norin 8', as a recurrent parent.

From various crosses involving 'St 1' as a donor, many stripe disease resistant cultivars such as 'Mineyutaka', 'Tamahonami', 'Musashikogane', 'Aoisora', 'Hoshinohikari', 'Tsukinohikari', etc. were developed one after another at several breeding stations. Consequently, severe damage caused by stripe disease has disappeared in the area where the resistant cultivars were widely planted to farmers' fields.

Breeding for resistance to other virus diseases is also conducted elsewhere in the world. For example, IRRI succeeded in developing resistant cultivars against grassy stunt, which is serious virus disease transmitted by brown plant hopper in the Asian tropics. Through an extensive mass screening at IRRI, none was identified to be resistant to grassy stunt among more than 70,000 germplasms collected by IRRI. Only one strain of wild species, *Oryza nivara* SHARMA *et* SHASTRY, was found to have resistance to grassy stunt, and was backcrossed with 'IR 24' as a recurrent parent. Then, grassy stunt resistance gene, *Gsv*, was incorporated into IRRI materials. Consequently many new IRRI lines become carriers of *Gsv* and are resistant to grassy stunt.

Rice yellow mottle disease is a virus disease transmitted by some kinds of leaf beetle in the tropical Africa. Mass screening at the International Institute of Tropical Agriculture (IITA) indicated that no Asian rice cultivars, *O. sativa*, was resistant and that a few strains were identified to be tolerant to the virus among the African rice cultivars, *O. glaberrima*. Some Asian rice type lines possessing yellow mottle disease tolerance from *O. glaberrima* were developed at IITA for further evaluating their commercial traits.

Blast disease caused by a fungus *Pyricularia oryzae* is the most serious rice disease which sometimes devastates rice production not only in Japan but also in all over rice cultivation areas. In Japan, the utilization of exotic germplasm was most emphasized to develop resistant cultivars against this serious disease. During 1920s, in the dawn of scientific rice breeding in Japan, the Aichi Agricultural Experiment Station started incorporation of a high level of blast resistance from a Japanese upland rice cultivar, 'Senshou', into Japanese paddy rice cultivars. 'Senshou' noted as Chinese origin was brought into Japan during 1890s. The semi-sterility of F_1s between 'Senshou' and Japanese paddy rices indicates a remote genealogical relation between them. After repeated multiple crossing between 'Senshou' and different paddy rice cultivars for eliminating the semi-sterility and poor agronomic traits of 'Senshou', 'Shinju' and 'Futaba' were developed as the first Japanese paddy rice type strains possessing the high level of blast resistance from 'Senshou'. Then, such cultivars as 'Wakaba', 'Ukonnishiki', 'Homarenishiki', 'Koganenishiki', 'Suzuhara mochi', etc. were released one after another as those possessing an effective level of stable resistance for blast-prone areas.

After utilization of resistance of 'Senshou', rice breeders in Japan tried to incorporate a high level of resistance from other exotic germplasm into Japanese paddy rice cultivars. A series of highly resistant cultivars like 'Kusabue', 'Yuukara', 'Ishikari', etc. were developed on the basis of a blast resistance gene, *Pi-k*, from *japonica* type rice in China, such as, 'Reishikou' or "Totou'. Similarly, 'Sanpuku', 'Minehikari', etc. were recommended as they possessed, at the same locus as *Pi-k*, $Pi\text{-}k^m$ allele from Chinese *japonica* cultivar, 'Hokushi Tami'. In addition to those, many new cultivars with true resistance gene were developed at several breeding stations in Japan, such as 'Yashiro mochi' with *Pi-ta* of 'Okaine' from Taiwan; 'Simokita' and "Tosasenbon' with *Pi-ta* of 'Tadukan' from the Philippines; 'Satominori', 'Akiji', 'Yamayutaka', 'Yamahikari', etc. with $Pi\text{-}ta^2$ of the same Philippine cultivar, "Tadukan'; 'Fukunishiki', 'Yamatenishiki', 'Uruma mochi' etc. with *Pi-z* of 'Zenith' from USA; 'Hamaasahi' with *Pi-b* of 'Milek Kuning' from Malaysia; and 'Toride 1' with $Pi\text{-}z^t$ of "TKM 1' from India.

Those resistant to blast owing to true resistance gene(s), however, were often broken down by an unexpected outbreak of blast disease when a new blast fungus race appeared virulent to the true resistance of these cultivars. Rice breeders in Japan, therefore, tried to incorporate a high level of field resistance to cope with unpredictable breakdown, and a high field resistance gene, *Pi-f*, was introduced into the rice stripe resistant strain, 'St 1', from an *indica* cultivar, 'Modan', at the National Chugoku Agricultural Experiment Station, then another high field resistance gene was introduced into 'Uruma mochi' at Kagoshima Agricultural Experiment Station through 'Ouu 244' from an original donor, USA cultivar, 'Zenith'. But, this high level of field resistance controlled by a single dominant gene was also found to be brokendown by appearance of virulent fungus races.

Severe outbreaks of bacterial leaf blight disease often occurred in Kyushu Region after rice plants were damaged by typhoon. The National Kyushu Agricultural Experiment Station, therefore, released some resistant cultivars, 'Asakaze', 'Nishikaze', etc., which possessed a bacterial leaf blight resistance gene, *Xa-1*. The gene *Xa-1* was found in the strain 'Kounou 35' which had been selected as a spontaneous variant having bacterial leaf blight resistance from an indigenous cultivar, 'Shinriki'. After the release of the resistant cultivars possessing *Xa-1*, a new bacterial strain virulent to *Xa-1* appeared in Beniya area of Kyushu. To solve this problem, an extensive mass screening was conducted to find out new genetic resources resistant to the new bacterial strain at the National Institute of Agricultural Sciences. One strain of indigenous cultivars, 'Wase aikoku 3', was identified as a resistant germplasm with *Xa-3* against the new bacterial strain. Then, the National Chugoku Agricultural Experiment

Station developed a new strain, 'Chuugoku 45', with a wide range of resistance by *Xa-3*.

3) Resistance to insect pest

Insecticide application for controlling insects such as plant hopper and leaf hopper often brought a severe resurgence of the pest in the Asian tropics, because some residuals of applied chemicals stimulate insect growth and the population of their natural enemies are reduced by chemicals used.

Brown plant hopper is one of the most devastating insects to rice cultivation, and is known as a vector of grassy stunt virus and ragged stunt virus. Many resistant cultivars were developed at IRRI against this insect through incorporation of resistance gene. As brown plant hopper can not survive winter in Japan, it migrates into Japan from the main land China every summer, and reproduce their population rapidly, causing serious hopper burn or "Tsubogare" in rice fields.

Breeding for brown plant hopper resistance has been conducted in Japan by using source materials from IRRI. An *indica* cultivar, 'Mudgo', was first selected at IRRI as a donor for brown plant hopper resistance possessing a resistance gene, *Bph-1*. The first Japanese paddy rice type resistant strain with *Bph-1* gene is 'Suitou chuukan bohon nou. 3', which is abbreviated as 'SCBN 3' and implies a paddy rice strain registered by Ministry of Agriculture, Forestry and Fisheries (MAFF) as a parental material for further improvement. It was developed at the National Agriculture Research Center (NARC) from a cross including 'Mudgo' as a resistance donor and Japanese paddy rice cultivars as recurrent parents. As an appearance of Biotype 2 of brown plant hopper which is not suppressed by the *Bph-1* gene was reported in the Asian tropics, NARC introduced from IRRI a new breeding material, 'IR 1154-243', possessing the different gene, *bph-2*, resistant to Biotype 2, and developed 'SCBN 4' with *bph-2* gene through a backcross including 'IR 1154-243' as a donor and Japanese paddy rice cultivars as recurrent parents.

To widen genetic background for brown plant hopper resistance in Japan, NARC introduced other genetic resources as donors possessing *Bph-3* and *bph-4* resistant to both Biotype 1 and 2 from IRRI. Then, 'SCBN 7' with *bph-4* of 'Babawee' from Sri Lanka and 'SCBN 10' with *Bph-3* of 'Rathu heenati' from Sri

Lanka were developed from backcrossed offsprings with Japanese paddy rice cultivars as recurrent parents.

Green leaf hopper is known as a vector of rice dwarf virus, and damages rice plants by sucking. As there is no cultivars resistant to green leaf hopper among Japanese paddy rices, NARC selected a Taiwanese *indica* cultivar, 'Pe bi hun', as a genetic resource for green leaf hopper resistance. Then, 'SCBN 2' possessing resistance to both green leaf hopper and rice dwarf disease was developed from a cross between 'Pe bi hun' as a donor and Japanese paddy rice cultivars as recurrent parents for two times backcrossing. Its green leaf hopper resistance is controlled by a single dominant gene, *Grh-1*, and its rice dwarf disease resistance is supposed to be expressed through resistance to the vector insect.

At the National Kyushu Agricultural Experiment Station, an Indian cultivar, 'C 203-1', was selected as a donor for green leaf hopper resistance, and was backcrossed three times with Japanese paddy rice cultivars, then 'SCBN 5' possessing resistance to both green leaf hopper and rice dwarf disease was developed. Furthermore, an Indian cultivar, 'Lepe dumai', was used as a donor for green leaf hopper resistance at the National Tohoku Agricultural Experiment Station, and was backcrossed with Japanese paddy rice cultivar, "Toyonishiki', then 'SCBN 6' possessing resistance to both green leaf hopper and rice dwarf disease was developed. Interrelationship among the resistance genes of 'SCBN 2', 'SCBN 5' and 'SCBN 6' is not yet studied.

Stem maggot causes so-called "Yariho" meaning a spear head panicle by eating damage to young panicle apex at booting stage. After a wide utilization of a stem maggot resistance gene, *Sm*, of indigenous cultivar, 'Sakaikaneko', stem maggot damage nearly disappears in Japan.

4) Tolerance to adverse environments

Cool temperature during summer frequently devastated rice production in the northern Japan, especially in the northernmost border of rice cultivation. Though Japanese rice cultivars in northern Japan were considered to have the highest level of cold tolerance, some land races in highland of the Asian tropics were identified to be promising resources for cold tolerance breeding through mass screening at IRRI. Those land races from the tropical highland might have been formed under continuous stress of cool temperature throughout their growth period. An Indonesian *javanica* cultivar, 'Silewah', which was collected at a highland with an altitude of 1,300m in Sumatra, was one of the selections evaluated as genetic resources for cool tolerance at IRRI. 'Silewah' was utilized as a donor for cold tolerance breeding at the National Hokkaido Agricultural Experiment Station, where the cold tolerance of 'Silewah' and that of Hokkaido cultivars were accumulated into 'SCBN 8' which revealed a high level of cold tolerance. Other genetic resources for cold tolerance were selected from *japonica* land races of Yunnan by the Sino-Japanese Cooperative Research Project between the Yunnan Academy of Agricultural Science P. R. China and the Tropical Agriculture Research Center (TARC) Japan. Those were 'Kunming xiaobaigu', 'Lijiang xintuan heigu', etc., and some promising strains with high cold tolerance were selected from crosses including these cold tolerant genetic resources in the project.

5) Cooking quality

Aroma may be one of promising characteristics for improving grain quality of rice in Japan. A Pakistani cultivar, 'Basmati', is famous in the world rice market for its outstanding aroma. Its price is estimated to be more than twice of ordinary rice. Some Japanese land races with an aroma type differing a little from the 'Basmati's have long been maintained in Japan, but they disappeared because of low yield, tendency to lodging and extremely long culm length. 'Miyakaori' with the Japanese type aroma and an improved plant type developed at Furukawa Agricultural Experiment Station in Miyagi Prefecture from a cross with an aromatic land race, 'Iwaga', is now expected to be a unique product in Furukawa area. A new long grain japonica cultivar with the 'Basmati' type aroma, 'Sari queen', developed at NARC from a backcross using 'Basmati 370' as a donor for aroma and Japanese paddy rice cultivars as recurrent parents, is also expected to become popular among young consumers who are free from traditional taste.

Another new type cultivar, 'Hoshiyutaka', was developed at the National Chugoku Agricultural Experiment Station as long grain *japonica* cultivar with high amylose content from a cross including *indica* cultivar, 'IR 8', as a high amylose parent. 'Hoshiyutaka' with a yield level 10 to 20% higher than ordinary cultivars is expected to meet a new type of rice at restaurants, such as pilaff and butter rice, although it is not suitable for a traditional way of home cooking due to hardness of cooked rice.

Purple pericarp grain of rice is produced among indigenous glutinous by tribal communities in Yunnan of China, and is considered to be of medicinal value. Its special color may be another promising character for expanding consumption of rice. When cooked 60% milling grain of rice, the color of cooked rice becomes completely purple, and purple pigment may be used for coloration of food as a natural product. Some improved glutinous strains with the purple pericarp were selected at Furukawa Agricultural Experiment Station for an unique local product in Miyagi Prefecture.

6) Traits for hybrid rice

A successful utilization of genetic resources for innovative breeding may be finding male sterile cytoplasm and its restorer gene. In P. R. China, hybrid rice is now planted to about one third of total paddy rice planting area, and it produces about a half of total rice production. Chinese hybrid rice was developed by utilizing cytoplasmic male sterility system. WA cytoplasm for male sterility of *indica* group was found in a wild rice population in Hainan Island by Prof. L. P. YUAN, Director of the Hunan Hybrid Rice Research Center, and a restorer gene for male sterility caused by WA cytoplasm was fortunately found among IRRI cultivars possessing good plant type, high yielding ability, resistance to diseases and semi-dwarf gene.

As the genetic diversity within *indica* group is much wider than that within *japonica* group, hybrid rices between *indica* Chinese male sterile lines and *indica* IRRI cultivars showed a high level of heterosis in yield without lodging problem, because both Chinese male sterile lines and IRRI cultivars carry the same semi-dwarf gene, *sd-1*. Furthermore, hybrid rice expressed disease resistance of IRRI cultivars due to dominant nature of resistance genes.

Genetic resources for cytoplasmic male sterility of *japonica* group, BT cytoplasm, was found in *indica* cultivar, 'Chinsurah Boro II', by Dr. C. SHINJO, Professor of Ryukyu University, and the restorer gene was introduced into Ponlai (Taiwan *japonica*) cultivar, 'Taichung 65', from some *indica* cultivars including 'Chinsurah Boro II'. Another male sterile cytoplasm for *japonica* group, LR cytoplasm, was found in a Myanmar cultivar, 'Lead rice', at the National Institute of Agricultural Sciences, and a restorer gene for LR cytoplasm was found in a Japanese upland rice cultivar, 'Damattero', at the National Hokuriku Agricultural Experiment Station.

It is expected: the more remote is the genealogical relation between parents, the higher is the degree of heterosis in yield of F_1 hybrids. Chinese hybrid rices succeeded in 20 to 30% yield increase compared with ordinary cultivars due their genetic diversity within *indica* group, but a yield increase of *japonica* type hybrid rice is expected to be less than 15% due to poor genetic diversity within japonica group. On the contrary, yield gains in the F_1 hybrids between indica and *japonica* group are estimated to be 30 to 40% due to the distant relation between *indica* and *japonica* parents. But actually yield of F_1 hybrids does not reach such an expected level due to partial sterility in *indica-japonica* hybrids.

TARC suggested a possibility of breakthrough in this semi-sterility problem of *indica-japonica* hybrids by utilization of wide compatibility gene, $S\text{-}5^n$, from Indonesian *javanica* cultivar, 'Ketan Nangka'. A set of $S\text{-}5$ multiple alleles is located between C (chromogen for pigmentation) and *wx* (glutinous endosperm) loci on chromosome 6 (new naming system proposed by the 2nd International Rice Genetic Symposium on May 18, 1990) : $S\text{-}5^n$ for wide compatibility cultivar, $S\text{-}5^i$ for indica cultivars, and $S\text{-}5^j$ for japonica cultivars. The genotype of $S\text{-}5^n/S\text{-}5^i$ and $S\text{-}5^n/S\text{-}5^j$ are fertile, but $S\text{-}5^i/S\text{-}5^j$ is semi-sterile due to partial abortion of gamates carrying $S\text{-}5^i$. TARC developed 'SCBN 9' with $S\text{-}5^n$ as a *japonica* type parental strain for mating with *indica* parent, and the *indica-japonica* hybrid rice cultivars with $S\text{-}5^n$ is being developed as super high yielders.

2. Wheat

1) Semi-dwarfism

The 1970 Nobel Prize for peace was awarded to Dr. N. E. BORLAUG, Centro Internacional de Mejoramiento de Maize y Trigo (CIMMYT), for his outstanding leading work, through which semi-dwarf high yielding Mexican wheat cultivars adapted to the tropics and sub-tropics were developed. A great number of people living in the Indian subcontinent were relieved from hunger by the success. The semi-dwarf gene of Mexican wheat is traced back to a Japanese wheat cultivar 'Norin 10', and has contributed to improvement of wheat cultivars in the world not only for the tropics and subtropics but also for USA, Europe and Australia.

One of the ancestors of 'Norin 10' was a Japanese indigenous cultivar 'Daruma' which was collected as a semi-dwarf popular cultivar in the Kanto region, Japan by the National Agricultural Experiment Station in 1917, and the other was 'Glassy fulz' which was selected in Japan for its glassy grain characteristics from a US cultivar 'Fulz'. 'Fulz daruma' derived from a cross between 'Glassy fulz' and 'Daruma' was again crossed with a US cultivar "Turky red' at Ehime Agricultural Experiment Station, and then 'Norin 10' was developed from offsprings of this cross at Iwate Agricultural Experiment Station in 1935.

This semi-dwarf cultivar 'Norin 10' was introduced to USA after the World War II by Dr. S. C. SALMON, a staff member of US Occupation Army, because he was so interested in a special semi-dwarf plant type of 'Norin 10' during his stay in Japan. Then 'Norin 10' was crossed with a US cultivar 'Brevor' at Washington State Agricultural Experiment Station, and some derivatives of this cross were sent to Dr. N. E. BORLAUG at the Wheat Improvement Project in Mexico. These breeding materials were further hybridized with Mexican indigenous cultivars and others, and then so-called Mexican wheat with semi-dwarfism and high yielding ability, such as 'Penjamo 62', 'Sonora 64', 'Mexipak 65', 'Ciano 65', etc., were developed at CIMMYT by Dr. BORLAUG. After that, the semi-dwarf gene of Japanese land race 'Daruma' returned to Japan with the Mexican wheat, and a semi-dwarf high yielding cultivar 'Haruyutaka' was developed at Kitami Agricultural Experiment Station from a cross with the Mexican wheat.

The other success of CIMMYT was development of so-called Veery'S' group cultivars which realized superior yield much higher than previous Mexican wheats. Veery'S' group cultivars were derived from a cross between semi-dwarf Mexican wheat with spring habit and European wheat cultivar with winter habit for expanding genetic diversity of Mexican wheat. Veery'S' group cultivars have 1RS-1BL reciprocal translocation chromosome between the rye chromosome (1R) and the common wheat chromosome (1B) through cultivar 'Kavkaz', a derivative of intergeneric hybrids.

2) Disease resistance

Following high yielding ability, disease resistance is another important trait to be introduced from various genetic resources. Breeding for leaf rust resistance has been conducted in many countries in the world. During Taisho era, when wheat breeding was initiated in Japan, an emmer wheat cultivar (*Triticum durum*, AABB) 'Beloturka' was used for introducing its leaf rust resistance gene to a common wheat (*T. aestivum*, AABBDD), and 'Norin 3' was developed from the interspecific hybrid at Hokkaido Agricultural Experiment Station in 1930.

Recently, the National Tohoku Agricultural Experiment Station started a wheat breeding program for leaf rust resistance by using a new method of chromosome engineering. Diverse genetic resources including related cultivated species and wild relatives were expected as sources materials for introducing leaf rust resistance gene(s). As the results of the project, 'Komugi chuukan bohon nou 1', abbreviation of which is 'KCBN 1' implying a wheat strain registered by MAFF as a parental material for further improvement, was developed by accumulating different resistance genes. One of them was from strain 'RW-12' possessing a dominant resistance gene on 6B chromosome from a wild emmer wheat (*T. dicoccoides*, AABB), and the other was from strain 'AR-1' with an incomplete dominant resistance gene on 1A chromosome from a Transcaucasian cultivated wheat (*T. thimopheevi*, AAGG). Then, 'KCBN 2' was developed by an intergeneric transfer of resistance gene from 8x *Triticale* (AABBDDRR) including a rye cultivar (*Secale sereale*, RR) 'Petkusa'. 'KCBN 3' was also developed by accumulating leaf rust resistance genes of a wild emmer wheat (*T. dicoccoides*) and *Agropyron intermedium*. Furthermore, an introduced strain 'Agrus', which had a reciprocally translocated chromosome between 7D chromosome of wheat and a part of *A. elongatum* chromosome carrying resistance gene, was utilized as a breeding material for widening genetic background.

Powdery mildew is one of the major wheat diseases in Japan. Fortunately, a powdery mildew resistance gene of the aforementioned emmer wheat cultivar 'Beloturka' was introduced into the 'Norin 3' together with the leaf rust resistance gene. The powdery mildew resistance gene of 'Norin 3' was transmitted to 'Norin 29', then from 'Norin 29' to 'Ushio komugi', and it was further transferred to 'Nishikaze komugi' and 'Fukuho komugi' through 'Ushio komugi'.

3) Quality characteristics

Grain quality of wheat in the southern Japan is much affected by scab disease as well as by sprouting or wetting by rain during ripening period in rainy season. As a result of mass screening for scab tolerance at the National Kyushu Agricultural Experiment Station, no scab tolerant cultivar was found among cultivars introduced from areas where rain falls rarely during ripening period, such as USA, Europe and Australia. Only, 'Sobaku 3' from P.R. China where the weather is moist during ripening period was identified to have a high level of scab tolerance. 'KCBN 4' was developed at the Station by combining scab tolerance of 'Sobaku 3' and that of a Japanese scab tolerant land race 'Nobeoka bouzu'.

4) Tolerance to acidic soils

In Japan, wheat has been planted mainly to paddy fields where soil acidity is mild due to irrigation for rice. Most of Japanese wheat cultivars, therefore, are sensitive to soil acidity, and have a tendency to grow extremely poor when planted to volcanic acid soils, which is phosphorus deficient and aluminum toxic. A land race 'Hiraki komugi' which had been planted to volcanic acid soils in Tottori Prefecture was identified to have tolerance to acidity. Tottori Agricultural Experiment Station, therefore, tried to introduce acidity tolerance of 'Hiraki komugi' into high-yielding modern cultivars by using recurrent backcross method, but the result was disappointing because of low yield of the progeny due to short panicle length from 'Hiraki komugi'.

CIMMYT expected to release Mexican wheat cultivars to vast plains in Brazil, but existing Mexican wheat cultivars did not grow well due to susceptibility to aluminum surplus soils. Along a plan to combine the aluminum surplus tolerance of Brazilian indigenous cultivars with high-yielding ability of Mexican wheat cultivars, CIMMYT succeeded in development of acidity-tolerant, semi-dwarf high yielding cultivars adapting to Brazilian plains.

5) Traits for hybrid wheat

Since the discovery of complete male sterility in wheat with the G type cytoplasm of *T. thimopheevi*, which was free from any obvious adverse side effects, the G type cytoplasm has been used almost exclusively as the source of male sterility for developing high-yielding hybrid cultivars all over the world, especially in USA. However, hybrid cultivars have not yet been commercially produced despite more than 30 years research efforts. Main reasons for such slow development was the necessity of multiple fertility-restoring genes for restoring complete fertility, or their insufficient function under unfavorable environmental conditions.

Recently, the Sv type cytoplasm of *Ae. kotschyi* and *Ae. variabilis* is considered to be a promising candidate as a male sterility source insteads of the G type cytoplasm. The Sv cytoplasm causes male sterility on a cultivar 'Salmon' derived from an octoploid *Triticale*, but the Sv type cytoplasm does not cause male sterility on usual common wheat cultivars. As the fertility-restoration gene *Rfv1* of usual common wheat cultivars is located on the short arm of 1B chromosome of common wheat, the wheat cultivars, such as 'Salmon' and 'Kavkaz', possessing 1RS-1BL chromosome derived from *Triticale* express male sterility for the Sv cytoplasm. Though the breeding of male sterile lines and their maintainers is not simple, it is extremely advantageous that some wheat cultivars can be used as restorers without any problems.

6) Reproduction habits

Unexpectedly, a valuable genetic resource for wheat breeding is obtained by haploid induction in the utilization of *Hordeum bulbosum*, which is a wild relative of barley. When common wheat cultivars are pollinated with pollen of *H. bulbosum*, chromosomes of *H. bulbosum* are completely eliminated from embryo cells during cell division after fertilization, and then young embryos possessing one set of common wheat chromosomes fail to grow before a complete seed stage due to lack of endosperm. NARC, therefore, applied an embryo rescue method to young embryos (1.4mm length) at two weeks after pollination, and succeeded in induction of haploid plants derived from maternal wheat individuals.

3. Barley

Barley is classified into three categories in Japanese market; "naked barley" which is mainly six-rowed barley for staple food, "hulled barley" which is mainly six-rowed barley for staple food, and "malting barley" which is two-rowed hulled barley for beer brewing. Barley has widely been cultivated in Japan as a winter crop in paddy field for its maturity earlier than that of wheat. Naked barley and hulled barley are mostly used as a row material for rolled barley which is a traditional staple food for mixing into rice meal. Recently, malting barley has taken the main place of barley production in Japan due to reduced consumption of rolled barley in shifting food habits. Areas of malting barley has increased year to year, because no other winter crops with such earliness exists.

1) Disease resistance

With the increase of barley cultivation, barley yellow mosaic disease (BYM) has widely spread throughout Japan.

BYM is a soil born virus disease transmitted through *Polymyxa graminis* in contaminated soil, and no chemical control measures against BYM is available. When barley is infected by BYM, besides yield reduction, its malting quality becomes poor due to increased nitrogen content. Farmers, therefore, were anxious to plant BYM resistant cultivars against this serious disease.

The Institute for Agricultural and Biological Sciences, Okayama University conducted a mass screening of BYM resistance for about 800 genetic resources which were collected and preserved by the institute, and selected a Chinese land race 'Bokusekikou 3' as a resistant germplasm against BYM. The institute further found that BYM resistance of 'Bokusekikou 3' was controlled by a major gene *Ym*. Recently, BYM resistant malting barley cultivars 'Miho golden' and 'Mikamo golden' were developed by Minami Kawachi Branch, Tochigi Agricultural Experiment Station after backcrossing to 'Bokusekikou 3' some malting barley cultivars, and BYM resistant two-rowed hulled barley cultivar 'Nishinochikara' with the same resistance gene *Ym* was also developed by the National Kyushu Agricultural Experiment Station.

2) High protein

Through an extensive screening using about 2,000 germplasm of US. World Barley Collection, Swedish Seed Association identified a high protein and high lysine strain 'CI 3947' among indigenous cultivars which were collected in Ethiopia about 50 years ago. It was renamed as 'Hiproly'. 'Ohmugi chuukan bohon nou 1' (abbreviation, 'OCBN 1', meaning barley strain registered by MAFF as a parental material for further improvement) with increased protein and lysine content by 20% and 36%, respectively, was developed at the National Shikoku Agricultural Experiment Station through recurrent backcrossing to 'Hiproly' with Japanese modern cultivar 'Nanpuu hadaka'. 'OCBN 1' has the same high yielding ability as the recurrent parent, and is expected to be a suitable parental material for improvement of nutritional value of barley as staple food and feeding material.

3) Haploid breeding

Haploid breeding is also a valuable measures to hasten fixation of hybrid materials for barley breeding. Barley cultivars bear immature haploid embryos by fertilization of pollen of wild barley *H. bulbosum*. This is the same phenomenon as found in wheat cultivars. The wild barley chromosomes are eliminated in an early embryogenesis. Then, the immature haploid barley embryos (ca. 1.4mm length) should be cultured in artificial media to get the haploid plants.

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Legumes

by

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CONTENTS

1. Soybean

Soybean (*Glycine max*) has been utilized as raw material for Japanese traditional foods, such as "tofu" (soybean curd), "natto" (fermented soybean) and "miso". Its nutritional value is very high for rice eaters as it supplies vegetable protein which can be obtained with a low price. Soybean, therefore, has been considered to be an important agricultural product for improvement of the nutritional balance in Japan, and is expected to play an important role to improve nutritional condition of people living in developing countries, where the population growth is one of the most serious problems.

1) Disease and pest resistance

Soybean production in Japan has been affected by various disease and insect pests. Resistance to sphaceloma scab caused by *Elsinoe glycines* was identified among Japanese indigenous cultivars, but resistant germplasms for soybean mosaic virus (SMV), soybean stunt virus (SSV) and soybean dwarf virus (SDV) were found only among alien genetic resources through an extensive screening.

SMV and SSV are transmitted by aphid which becomes viruliferous by sucking on virus-infected plants which grow from infected seed. The two virus are epidemic throughout Japan. Chemical control against SMV and SSV is very much difficult, because the diseases are easily transmitted by short time sucking on healthy plants by viruliferous aphid. Besides yield reduction in virus-infected plants, commercial value of infected soybean grain much decreases due to poor grain quality with brownish yellow specks on grain surface.

SMV is classified into A, B, C and D strain, and SSV into A, AE, B, C and D strain. Among Japanese indigenous and improved cultivars, some cultivars were found to be resistant to A, B strain of SMV, but so far, no cultivar was identified to be resistant to all the strains of SMV and SSV. Through a mass screening conducted at the Nat'l Tohoku Agr. Exp. Stn., a USA cultivar 'Harosoy' was identified to have resistance to existing SMV and SSV strains except for B strain of SMV. 'Harosoy', therefore, was employed as a donor for SMV and SSV resistance, and was crossed with 'Nema shirazu' which has resistance to A and B strain of SMV together with resistance to soybean cyst nematode (*Heterodera glycines*) and sphaceloma scab. From this cross, a new cultivar 'Dewa musume' with resistance to all the existing strains of SMV and

SSV together with resistance to soybean cyst nematode and sphaceloma scab was developed in 1977 after subsequent selections under disease pressure in SMV and SSV epidemic area. Then, the Nat'l Tohoku Agr. Exp. Stn. devised an artificial inoculation method for testing resistance to each strain of SMV and SSV independently, and 'Suzuyutaka' with resistance to all the existing strains of SMV and SSV was developed in 1982 by utilizing the new artificial inoculation method. 'Suzuyutaka' became the leading cultivar at Kanto, Tozan and Tohoku District due to its high yielding ability with wide adaptability, good grain quality and resistance to soybean cyst nematode besides resistance to SMV and SSV.

SDV was found in Hokkaido, the northern most region in Japan, during 1950s, and it is mainly transmitted by foxglove aphid, *Aulacorthum solani*, from virus infected clovers (*Trifolium* sp.) beside soybean fields. Through a mass screening of SDV resistance conducted at Hokkaido Central Agr. Exp. Stn., 'Ouhouju' and several other alien cultivars were identified to have a high level of tolerance to SDV. 'Ouhouju' was a selection from Chinese land race 'Yonryuukou' which had been collected from Chee Ring Province, China by the Agr. Exp. Stn. of South Manchurian Railway Co. before the World War Ⅱ. 'Ouhouju' does not have complete resistance like immunity, but has a high level of tolerance like field resistance. "Tsuru kogane' possessing a high level of SDV tolerance and good agronomic traits was developed from a cross including 'Ouhouju' as a donor at Hokkaido Central Agr. Exp. Stn. in 1984.

2) Pest resistance

Various insects attack soybean plants. Of them, a soybean beetle (*Anomala rufocuprea*) often shows severe outbreak in volcanic soil fields of plain area in Kanto District. A Japanese land race 'Aoshouryuu' was found to have tolerance against the soybean beetle by carefull observation at the Nat'l Inst. of Animal Husbandry. From a cross including 'Aoshouryuu' as a donor, 'Hime shirazu' was developed in 1970 as a green forage crop cultivar possessing tolerance to the soybean beetle, but its grain quality was too poor for human consumption due to small size with dark brown eye. Its leaf is thick, and a whole plant is covered with thick brownish rough hairs. 'Hime shirazu' has high tolerance not only to the soybean beetles but also to larvae of a bean blister beetle (*Epicauta gorhami*) and to larvae of a tobacco cutworm (*Spodoptera litura*).

Yield of soybean has been severely affected by soybean cyst nematode (SCN) with the increase of its population by continued planting of soybean. As no effective chemical control measures against SCN are established, a crop rotation system is essential to decrease SCN population in contaminated fields together with planting of SCN resistant cultivars.

Through a mass screening of indigenous cultivars for SCN resistance conducted by the Nat'l Tohoku Agr. Exp. Stn., 'Geden shirazu' was identified to have SCN resistance. Then, a SCN resistant cultivar 'Nema shirazu' was released in 1961 by a pure line selection from 'Geden shirazu' population which had been collected at Hataya Village, Senhata Gun, Akita Prefecture. The other SCN resistant cultivar "Toyosuzu' was developed in 1966 at the Hokkaido Tokachi Agr. Exp. Stn.(HTAES) from a cross with 'Geden shirazu 1' possessing the same resistance gene as 'Nema shirazu'. As the planting area of "Toyosuzu' was expanded, a new biotype of SCN virulent to "Toyosuzu' appeared at Tokachi District in Hokkaido. To meet this problem, HTAES conducted an extensive screening to find out new resistant germplasm against the new SCN biotype, and 'PI 84751' derived from Chinese land race 'Peking' was identified as a parental materials for further breeding to strengthen SCN resistance. Though 'PI 84751' has a high level of resistance to SCN biotypes including the new one, breeding of new cultivars possessing large grain size with yellow seed coat and yellow eye was very difficult because of a close genetic linkage between the strong resistance to SCN and the small grain character with dark brown seed coat of 'PI 84751'. As the first step of breeding for resistance to the new SCN biotype, 'Suzuhime' possessing SCN resistance and small grain size with yellow seed coat was developed as a new cultivar suitable for "natto" (fermented soybean) making in 1980 at HTAES. Successful breeding of 'Suzuhime' was a result of genetic recombination between the SCN resistance and the seed coat color.

3) Character for mechanized harvest

So far, soybean has been planted mainly to infertile farms in Japan, but recently soybean planting to fertile farms which were changed from paddy farms becomes popular in Japan due to the change of government policy. The Japanese soybean cultivars, adapted to rather infertile farms, have a tendency to lodge at fertile farms and do not adapt to mechanized harvesting. Chushin Agr. Exp. Farm of Nagano Agr. Exp. Stn. employed a USA cultivar 'Lee' as a breeding material for improving adaptability to mechanized harvesting. Then, from a cross including 'Lee', "Tamahomare' has been developed in 1980 as a high yielding cultivar with lodging resistance acceptable in fertile farms, but its grain quality is insufficient for raw materials of the Japanese traditional foods, because such characteristics of USA cultivars as high oil content and low protein content were transmitted to "Tamahomare' from 'Lee' together with the lodging resistance.

4) Nutritional content

Soybean is called as "Meat from Farm" due to its high protein content, but insufficient in the amount of sulfur containing amino acid (methionine and cysteine) out of total amino acid composition. The insufficiency in sulfur containing amino acid is considered to be a limiting factor of nutritional value of soybean. Major proteins of soybean are 7S and 11S globulin, and sulfur containing amino acid is less in 7S globulin than in 11S globulin. To improve the nutritional value of soybean, increasing of 11S globulin content and 11S/7S globulin ratio, therefore, may be an important breeding objective .

Crop Breeding Lab. of Iwate Univ. evaluated more than 1,700 germplasms for this trait. Only two cultivars, 'Masshoku mame' (Kou 503) and 'Keburi', were identified to be deficient in a part of subunits of 7S globulin. Though 7S globulin subunit is consisted in α, α' and β subunit, 'Masshoku mame' (Kou 503) reduced α and β subunit by about half to one third of ordinary ones, and 'Keburi' is completely deficient in α' subunit. By combining both genetic factors, some newly developed experimental strains decreased their 7S globulin content about one third of ordinary ones, and increased their 11S globulin content, indicating a possibility of improving the nutritional value of soybean.

Other defect in the nutritional quality of soybean are some inhibitors contained in the bean, which lower digestibility and protein efficiency ratio. Of them, tripthin-inhibitor inhibits action of tripthin, an enzyme for digesting protein in the stomach of human being and animals. There are two types of tripthin-inhibitor, the Kunitz type and the Bowman-Brink type. Two Korean cultivars, 'Kinzu' and 'Hakuta', were found to be deficient in the Kunitz type inhibitor, but no germplasms which lacks the Bowman-Brink type inhibitor was identified so far. Nevertheless, there is a possibility that the deficiency in the Bowman-Brink type inhibitor will be found among other germplasms or by mutation breeding. As the deficiency of the Kunitz type inhibitor is controlled by a single major gene, incorporation of this character into modern cultivars will be performed without much difficulty.

An enzyme, lipoxygenase, in soybean grain produces n-hexanole which causes greenish smell. There are three isozymes of lipoxygenase in soybean grain, namely L-1, L-2 and L-3. Though the lipoxygenase for the greenish smell is inactivated by heat treatment, the treatment converts the protein into insoluble type, and lowers the nutritional value and processing quality. There is a possibility for a genetic elimination of lipoxygenase by a discovery of genetic resources which are deficient in active lipoxygenase. Through an extensive screening for lipoxygenase deficient germplasm conducted by Crop Breeding Lab. of Iwate Univ., 'PI 86023' was identified to be L-2 deficient germplasm, and 'Natsu wase' and 'Ichigou wase' were identified to be L-3 deficient germplasms. While, 'PI 33226' and 'PI 408251' were selected as L-1 deficient germplasms by Illinois Univ. of USA from 6,000 germplasms preserved in USA. Consequently, all three lipoxygenase deficient types were found. Of them, the L-2 deficient type extremely reduces n-hexanole production, and the double deficient type lacking L-2 and L-3 shows practically no greenish smell. Soybean milk which will be produced from lipoxygenase deficient soybean can be taken easily by peoples in the world as it lacks greenish smell, and will contribute to improve nutritional condition of children in developing countries.

2. Azuki bean

Azuki bean (*Vigna angularis*) has been planted together with soybean from ancient times in Asia. Though soybean becomes popular throughout the world today, azuki bean is only planted in Asia. In Japan, azuki bean has been used for making "sekihan" (red cooked rice) on days of celebration or as raw materials of "an" (bean jam) for Japanese traditional cake and "shiruko" (red bean soup), because a special taste of azuki bean is preferred by Japanese people.

1) Disease and pest resistance

There are many disease and insect pests which attack azuki bean plants in Hokkaido, the main azuki bean production area in Japan. Of them, brown stem rot (BSR) caused by *Phialophora gregata* is a soil born disease, and causes serious damage in azuki bean production at farms converted from paddy farms in Hokkaido. Its causal fungi invade azuki bean plants from roots, and increase their population density in contaminated farms through continuous planting of azuki bean plants. The only effective control measures is a long term crop rotation and planting of resistant cultivars. Through an extensive screening at HTAES, 'Akamame' (introduced from Korea), 'Maruba' and 'Kuro azuki' (Okayama) were identified to be resistant to BSR. 'Hatsune shouzu' with BSR resistance was developed at HTAES in 1985 from a cross including 'Akamame' as a donor of resistance. It was selected at BSR contaminated fields and by artificial inoculation technique. However, the causal fungi of BSR are differentiated into several specific races, and a race virulent to 'Hatsune shouzu' appeared already in Hokkaido. To meet this problem, 'Azuki chuukan bohon nou 1' was selected in 1985 as a parental strain possessing a wide range of resistance to BSR races and improved agronomic traits from a cross with an indigenous cultivar 'Kuro azuki' (Okayama).

Phytophthora stem rot (PSR) caused by *Phytophthora vignae* often occurred epidemic at upland farms converted from paddy fields when farms are flooded by heavy rain. Azuki bean production at such converted farms badly suffers from PSR in a rainy year. To widen genetic diversity of azuki bean in Hokkaido, HTAES conducted crossing between indigenous cultivars in Hokkaido and land races in the Main Island, Honshu. Hybrid populations of some crosses including a Honshu land race 'Noto azuki' which had been collected at the Osaka Cereal Market, was repeatedly selected from early generation at PSR contaminated farms, and a SR resistant cultivar 'Kotobuki shouzu' was developed at the Hokkaido Central Agr. Exp. Stn. in 1971. This is a good instance in which a collection of genetic resources in city markets is useful.

Azuki bean production in Hokkaido fluctuated year to year with the temperature during cropping season, and much decreased in the year of low temperature. Cold tolerance, therefore, is one of the important targets in the azuki bean breeding in Hokkaido. HTAES conducted an extensive screening for cold tolerance, and a land race in Hokkaido, 'Madara shouryuukei 1' was selected as a parental material for cold tolerance. Though 'Madara shouryuukei 1' has a high level of cold tolerance revealed in a precise test in phytotron, its commercial value is low because of poor seed coat color with red spots. Therefore, a mass selection of offsprings of crosses including 'Madara shouryuukei 1' was first conducted for seed coat color, and a cold tolerant cultivar 'Hayate shouzu' was developed in 1976 after severe selection in breeding farms in the year of low temperature. 'Tsuru shouzu' and 'Tsurugi 3' were later identified to be cold tolerant, and 'Toiku 77' was selected as a parental strain which accumulated the cold tolerance of both parental cultivars. Then, 'Erimo shouzu' which combined cold tolerance, good grain quality and high yield was developed from a cross between "Toiku 77' and 'Kotobuki shouzu' in 1981 at HTAES.

3. Common bean (Kidney bean)

Common bean (*Phaseolus vulgaris*) is considered to have been cultivated in Middle America since 5,000 years ago, and became a principal food crop for small farmers in many countries of tropical America and Africa. Common bean cultivation is a major means of supporting life for five million people estimated in the region. Common bean was introduced into Japan during Meiji era as one of major crops in Hokkaido. Recently, two varietal groups, Kintoki group (red seed coat) and Tebo group (white seed coat), are dominant in Hokkaido. Of them, Kintoki group is mainly used for processing a sweet boiled bean, and Tebo group is utilized as a raw material for "shiro-an" (white bean jam) making.

1) Adaptability to mechanization

The plant of main cultivars of Tebo group is semi-vine type with an indeterminate growth habit, which is not easily handled in mechanized cultivation and harvesting. To adapt the crop to mechanized farming by changing plant type of Tebo group, HTAES made a cross between a Hokkaido semi-vine type cultivar, 'Kairyo outebou' and a USA cultivar 'Sanilac Pea Bean' which grow in bush type with determinate growth habit while being early maturing and cold tolerant. A bush type strain "Toiku A-19' was selected from this cross, and then it was crossed to a cold-tolerant USA cultivar, 'Improved White Navy'. Consequently, a bush type cultivar 'Hime tebou' was developed in 1976. 'Hime tebou' is early maturing, lodging resistant and cold tolerant, and adapted to mechanized farming especially to harvesting by bean harvester owing to its plant type.

2) Disease and pest resistance

Major disease of common bean is anthracnose caused by *Colletotrichum lindemuthianum*. Anthracnose is transmitted by contaminated seeds into common bean fields, and develops black lesions on cotyledons just after germination. Conidia from black lesions move with rain water on soil surface, and cause secondary infection to other healthy plants. Common bean production, therefore, suffered from severe epidemic of anthracnose which occurred in the years with heavy rainfall. The causal fungi differentiated into several specific races. No common bean cultivar planted in Japan showed resistance to all the races except a newly developed cultivar of Kintoki group, 'Tanchou kintoki'. Another multiracial resistant cultivar, 'Widusa' from Netherlands was selected by HTAES as a donor for improving a susceptible cultivar 'Hime-Tebou' by backcrossing.

Common bean grain badly suffers from bean weevils during storage in Latin America and Africa, and the storage loss in Latin America is estimated to reach around 13 - 15%. The Centro Internacional de Agricultura Tropical (CIAT) evaluated more than 8,000 cultivated common bean accessions for bean weevil resistance, and no cultivar was found to show an adequate level of resistance. Only some wild beans which had been discovered in western Mexico were identified to have a high level of resistance. It was found that the wild beans produce some proteins different from those in cultivated common beans, and that the resistance to weevils is controlled by two kinds of protein contained in seeds of the wild beans. Of them, an arcelin, which was named after the town Arcelia in Mexico where the wild beans were discovered, drastically reduces the number of adult weevil of *Zabrotes subfasciatus*, a species of bean weevil adapted to the tropical zone. And probably a glycoprotein is the other antibiotic protein which inhibits growth of *Acanthoscelides obtectus*, a species of bean weevil adapted to the temperate zone. As new strains developed at CIAT possessing both kinds of protein show resistance to both the tropical and temperate zone weevils, they are expected to contribute to improvement of human life in Latin America and Africa where common bean is a principal food crop for small farmers.

4. Cowpea

Cowpea (*Vigna unguiculata*), also called southern pea or blackeyed pea, has been cultivated in many developing countries in the world. Cowpea is well adapted to stressed conditions in the tropics, and has excellent nutritional qualities. It is grown extensively in 16 countries in Africa, which produces two-thirds of the world production. In the tropical Africa, cowpeas are primarily stored in a form of dry seed, and cooked as a pulse in a large variety of dishes.

The tender green leaves are also cooked like spinach or as a relish. Green beans or cut green pods are used as a vegetable throughout the world.

International Institute of Tropical Agriculture (IITA) in Nigeria is the mandatory institute for collection and preservation of cowpea genetic resources. More than 12,000 accessions from all over the African continent are preserved in IITA, and are evaluated for their agronomic traits to utilize them as breeding materials.

Indigenous cultivars are low yielding with indeterminate and climbing growth habit that requires trellis support. And their maturity is late due to photoperiod sensitivity. IITA, therefore, has tried to improve yielding ability of cowpeas by incorporating new plant characteristics such as determinate and bushy growth habit, early maturity by photoperiod insensitivity, and multiple resistance to various diseases and insect pests using the collected genetic resources,.

'IT84S-2246-4', a newly developed cultivar by IITA, has a high yielding ability of 2 ton/ha with protein content of 30% and a multiple resistance to major diseases and insect pests in Africa, such as resistance to cowpea yellow mosaic, anthracnose, *Cercospora cruenta*, *C. canescens*, bacterial pustule, web blight, aphid and bruchid, and moderate resistance to cowpea aphid-borne mosaic, brown blotch, scab, bacterial blight and thrips.

5. Peanut

Peanut (*Arachis hypogaea*), also called groundnut, is believed to become a cultivated crop more than 3,000 years ago at mountainous and hilly areas of Andes in South America, and it was first introduced into Japan during Meiji era. Only alien germplasms have been employed for varietal improvement, because no indigenous germplasm exists in Japan. Peanuts are classified into two groups, namely the Verginia type with large grains and the Spanish type with small grains. Only the former type is planted in Japan at present, because consumption of peanut in Japan is limited in making roast pods and roast grains.

The optimum growth temperature for the Verginia type is 25 to 30°C, and its growth requires a long period in Japan. Cultivation of the Verginia type, therefore, suffers from such problems as over growth of vegetative parts and rust damage caused by *Puccinia arachidis* in a warm region and a limited period of the optimum growth temperature in a cool region. While the Spanish type can complete its growth period in Japan, because its optimum growth temperature is 23 to 25°C.

Chiba Agr. Exp. Stn., which is the sole breeding center for peanut in Japan, has made a lot of crosses between the two groups. New cultivars, 'Wase tairyuu' and 'Tachimasari', which combined the large grain size of the Verginia type and the growth habit of the Spanish type adaptable to relatively cool condition, were released in 1972 and 1974, respectively. The two cultivars made it possible to cultivate peanut even in the Tohoku region in the north of Japan, where the newly developed mulching cultivation technique is adopted by which soil temperature is kept high during early growth period.

In addition to the above mentioned, an introduced strain '334-A' which was derived from an inter-group hybrid between both types in USA was used as a parent to crosses at Chiba Agr. Exp. Stn. It has resistance to stem rot caused by *Diploidia natalensis*, but its disadvantageous characteristics in Japan are late maturity, small grain size and erect type growth habit of the Verginia type. From the cross with '334-A', a new cultivar 'Nakate yutaka' with medium maturity, good grain quality and high yielding ability was developed in 1979. The success of these newly developed cultivars means the establishment of new growth habit adapted to Japanese environment.

A Verginia type strain 'PI 315608' of Israeli origin was introduced from USA, and used as a resistant parent for rust caused by *Puccinia arachidis*. But no variety with the rust resistance was yet developed, because susceptibility to peanut mottle virus was not eliminated from the offsprings due to a linkage between both the characteristics.

As a result of mass screening conducted at Chiba Agr. Exp. Stn. for resistance to scab caused by *Sphaceloma arachidis*, Bolivian cultivars 'Granos pálidos 1' and 'Guay curú 1' were selected as resistant genetic resources, and are being used as parents for scab resistance breeding.

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in Hyderabad, India, which is a mandatory institute for peanut breeding in an international network for plant breeding, preserves more than 8,500 genetic resources, and has found some valuable materials for resistance to various diseases of peanut among its huge collections. These genetic resources will be used as breeding materials in Japan in future.

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Tuber and Root Crops

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CONTENTS

1. Potato (Irish potato)

1) Late blight

Cultivated potatoes originated from Peruvian and Bolivian Andes in the South America. Potatoes planted to those regions belong to several different species of diploid, triploid, tetraploid, pentaploid and hexaploid. Some diploid, triploid and tetraploid wild relatives, which are promising genetic resources, still exist in the Andean regions.

A cultivated species characterized by small tuber size, *Solanum stenotomum* and *S. phureja*, which are cultivated by peasants in villages in the Andes, are diploid species, while our modern cultivated potato, *S. tuberosum*, is tetraploid which is traced back to a large tuber-sized Andean cultivated species *S. andigena*. As no wild type of *S. andigena* is found in the Andean regions, this species may be originated by duplication of the genome of cultivated diploid potatoes with small tuber. Thus, the tetraploid cultivated species had been established near the Lake Titicaca in Peru since about 500 BC.

Potatoes settled in Europe after it was introduced from the South America in early 16th century. Then, Dutch traders based at Nagasaki City brought potatoes into Japan during Tensho era (1573-1592). Potato cultivation in Japan was first recorded in the middle of the 17th century, when it was recommended by local officers as a suitable crop in famine. Then, potatoes became popular in Japan after the late Meiji era around 1900.

A historical famine resulted from a severe outbreak of late blight (*Phytophthora infestans*) happened in Ireland over three years in the middle of the 19th century. In the famine, several hundred thousand people were starved to death, while several hundred thousands migrated to the North America. Since then, the resistance to late blight has been one of the most important objectives of potato breeding.

The hexaploid wild species of Mexican origin, *S. demissum* was utilized as a donor of late blight resistance in Japan, USA and Europe. Some late blight resistant cultivars with one or two true resistance gene(s) of *S. demissum* were developed. Of them, 'Kennebec' which was introduced into Japan from USA immediately after the 2nd World War revealed a high level of resistance to the late blight owing to *R1* gene at the period of its introduction, but it became susceptible within few years because of an emergence of new virulent fungal races. Four true resistance genes, *R1*, *R2*, *R3* and *R4* of *S. demissum*, were introduced to some cultivars or strains. However, those possessing each of these four true resistance genes became susceptible, and those possessing two, three or four genes also became susceptible without any cumulative effect of the true resistance genes.

To cope with this problem, intensification of field resistance to the late blight was started as a new breeding strategy. As *S. demissum* also has a high level of field resistance to the late blight besides its true resistance genes, the Nat'l Hokkaido Agr. Exp. Stn. used *S. demissum* as a donor of field resistance, and developed a new cultivar 'Rishiri' possessing a considerably high level of field resistance together with *R1* gene by a backcrossing program in 1960.

The diploid wild relative species *S. stoloniferum* possessing a high level of field resistance to the late blight shows cross-incompatibility with cultivated tetraploid potatoes. To breakthrough the cross-incompatibility due to different level of poliploidy, a 4x-amphidiploid was produced by doubling of chromosome number of F1 hybrid between *S. stoloniferum* and cultivated diploid species *S. phureja*. This 4x-amphidiploid was cross-compatible with tetraploid cultivars, and was backcrossed with tetraploid cultivars. Then, 'Hokkai 56' was selected as a parental strain which had a high level of field resistance together with *R2* gene of *S. stoloniferum*.

2) Golden cyst nematode

This nematode (*Globodera rostochiensis*) is one of the serious pests for potato after its invasion of Japan after the 2nd World War via "guano" from Chile. As there is no measures to control the golden cyst nematode in soil, so far planting of resistant cultivars is only a practical countermeasure. The resistance to golden cyst nematode was found in *S. andigena* which is supposed to be an ancestral species of cultivated tetraploid potatoes. Golden cyst nematode resistant cultivars possessing *H1* gene of *S. andigena* were developed in Europe where the nematode contaminated farmers' fields since a long time ago.

From the resistant cultivars with *H1* gene developed in Europe, a German cultivar 'Tunika' was selected as a recommended cultivar adaptable for the area contaminated by golden cyst nematode in Hokkaido, but it was not accepted by farmers because of insufficient adaptability to an environment in Hokkaido. The Nat'l Hokkaido Agr. Exp. Stn., therefore, started the breeding for resistance to golden cyst nematode by using European resistant cultivars including 'Tunika', using a new effective testing method for golden cyst nematode resistance in early generations. Consequently, so far following resistant cultivars with *H1* gene were developed: 'Toyo akari' in 1987 and 'Kita akari' and 'Ezo akari' in 1988.

3) Frost tolerance

Potatoes often suffer from serious frost damage in their early growth period and/or maturing period. A tetraploid wild relative species, *S. acaule*, existing at high mountainous area in the Andes shows an extremely high level of tolerance to frost damage. It tolerates well hard frost which usually results in death of cultivated potatoes. Though *S. acaule* is cross-incompatible with tetraploid cultivars, octoploid *S. acaule* which was produced by doubling of chromosome number becomes cross-compatible with tetraploid cultivars. Breeding for frost tolerance has been conducted by the Nat'l Hokkaido Agr. Exp. Stn. by utilizing octoploid *S. acaule* as a donor for backcrossing with tetraploid cultivars. As the backcrossing increased, agronomic traits of breeding materials became more similar to those of cultivars, and the level of tolerance to frost damage gradually decreased, but some breeding strains with a much higher level of frost tolerance have been selected.

Other useful genetic resources possessing resistance to some virus diseases and to insect pests, such as 28-spotted lady beetle (*Henosepilachna vigintioctopunctata*) and others, were identified among wild relatives, and are promising for future breeding program.

4) High starch content

While being a food crop, potato is also utilized as raw materials for starch industry. The cultivars for starch production must have a high yielding ability with high starch contents. A German cultivar 'Hochprozentige' possessing starch contents of 25% was selected at the Nat'l Hokkaido Agr. Exp. Stn. as a cross parent to develop a high starch cultivars for starch industry, though it was not used for ordinary cultivation because of its low yielding ability with small tubers. Then, a cultivar 'Bihoro' with an extremely high starch contents up to 27% was developed in 1969 from the cross including 'Hochprozentige', but

'Bihoro' failed to be popular because of low yielding ability and its insufficient agronomic traits.

To widen the genetic background for high starch contents breeding, the Nat'l Hokkaido Agr. Exp. Stn. adopted a diploid wild relative species *S. chacoense* possessing extremely high starch contents. As *S. chacoense* is cross-incompatible with tetraploid cultivars, it was crossed with a diploid cultivated species *S. phureja*, then 4x-amphidiploid being cross-compatible with tetraploid cultivars was produced by doubling chromosome number of the F_1 plant. After three time backcrossing with tetraploid cultivars, 'Konafubuki' with high starch content more than 22% was developed at Hokkaido Konsen Agr. Exp. Stn. in 1981. 'Konafubuki' is considered to be an epoch-making cultivar for starch production, because its yielding ability is high besides high starch contents, and its agronomic traits including late blight resistance by *R1* and *R3* genes are acceptable by farmers.

5) Haploid breeding

Small tuber-sized cultivated diploid species *S. phureja* is a valuable germplasm which contributed to the development of haploid breeding technique in tetraploid potatoes. When tetraploid cultivars were pollinated with pollen of *S. phureja*, the greater part of crossed seeds produced double haploid plants instead of triploid F_1 hybrids. The frequency of haploid induction of *S. phureja* showed big differences among strains used, and some strains formed brownish spots on surface of hybrid seeds, though they did not formed brownish spots on haploid seeds. Therefore, when such strains were used as a pollen parent for haploid breeding, hybrid seeds were efficiently eliminated by existence of brownish spots on their surface, and only haploid plants were developed from the remainder. The Nat'l Hokkaido Agr. Exp. Stn. selected such special strains possessing high haploid induction frequency.

6) International net work

The Centro Internacional de la Papa (CIP) in Peru is a mandatory institute for collection and preservation of potato genetic resources in the worldwide network under the CGIAR System. CIP is developing an *in vitro* preservation technique of virus free individuals, and distributes these genetic resources to researchers in the world upon their requests.

2. Sweet potato

1) Origin and genetic diversity

Sweet potato (*Ipomoea batatas*) is considered to be originated in tropical areas of Mexico to Guatemala in the Middle America, especially in the coastal area of the Gulf of Mexico. An ancestor of sweet potato is traced back to a diploid wild species *I. trifida*. Firstly, a triploid *I. trifida* might be resulted from a cross between spontaneous tetraploid and original diploid *I. trifida*, then, a hexaploid *I. trifida* might be developed by spontaneous chromosome doubling of the triploid plants. Then cultivated sweet potatoes were developed from the hexaploid *I. trifida* in about 2,000 BC. Thereafter, the sweet potato was distributed to Polynesia, New Zealand and New Guinea from the South America across the Pacific Ocean far before the discovery of America by COLUMBUS. COLUMBUS was known as the first person who brought sweet potatoes into Spain together with irish potatoes, but sweet potatoes did not become popular in Europe.

Sweet potato was introduced into Okinawa in 1605 through Fujiang Province of China, and contributed to relieve local residents from hunger caused by typhoon disaster. Then, sweet potato was brought into Kyushu, and it was appreciated as a suitable crop at famine by drought and/or typhoon, and it became popular in the southern Japan before the middle of the 18th century.

The number of sweet potato cultivars which were initially introduced into Japan and those introduced before Meiji era was supposed to be two or three and about ten, respectively. Therefore, the genetic diversity of indigenous sweet potato germplasm was very narrow in Japan. Furthermore, only five land races, 'Shichifuku', 'Genki', 'Taihaku', 'Choushuu' and 'Benikawa', were used as parents for breeding in Japan because of self- and cross-incompatibility within a compatible group. Consequently, improved sweet potato cultivars which were developed from crosses among the five land races also contained genetic diversity too narrow to rise the yield level of sweet potato in Japan.

2) Improvement for starch yield

To expand the genetic background of sweet potato germplasm in Japan for elevating the yield level and starch contents, utilization of new germplasm from abroad was expected to be a breakthrough for rapid progress. For this purpose, an Indonesian cultivar 'T No.3' and a USA cultivar 'Perican Processor (L-4-5)' were employed as parents for mating with Japanese cultivars. As a result of expanded genetic diversity, an epoch-making cultivar 'Koganesengan' was developed in 1966 at the Nat'l Kyushu Agr. Exp. Stn.. 'Koganesengan' has starch contents of 23-27%, about 3% higher than the control, and revealed fresh weight yield higher by 50-80% than the control, doubling the starch yield per unit area.

By further improvement, a cultivar High-Starch was developed at the Nat'l Agr. Res. Cent. in 1988 as a raw material for starch production. When compared with 'Koganesengan', High-Starch is about 5% higher in starch contents, and 10-30% higher in starch yield per unit area. Its extremely high starch yield per unit area is remarkable as an elite cultivar and a valuable germplasm for starch production in the world.

3) Utilization of wild relatives

The expansion of genetic diversity of sweet potatoes in Japan was promoted rapidly by utilizing a wild relative species 6x *I. trifida* (KL 123-11). The Nat'l Kyushu Agr. Exp. Stn. succeeded in developing a F_1 hybrid between 6x *I. trifida* and a USA cultivar 'Perican Processor (L-4-5)', and made backcrossing two times with Japanese cultivars. As the first result of utilizing 6x *I. trifida*, 'Minamiyutaka' was developed in 1975. 'Minamiyutaka' shows specific adaptability to temperature and day length condition during cropping season in the southern Kyushu, and has resistance to black rot caused by *Ceratocystis fimbriata*. In addition to these desirable agronomic traits, 'Minamiyutaka' has resistance to root-knot and root-lesion nematode which was never identified among existing cultivars, and has a superior ability in storing fresh sweet potatoes. These new characteristics are considered to be introduced from the 6x wild relative germplasm.

4) Consumer quality

Expanding consumption of sweet potatoes is expected by developing new cultivars with changed taste to meet diverse preferences. The high carotene contents cultivar 'Benihayato' which contains 11.8 mg/100g of carotene, about 30 to 40 times that of ordinary cultivars, was developed in 1985 from a cross between a Japanese cultivar and a high carotene contents cultivar 'Centennial' from USA. 'Benihayato' is expected to be utilized as materials of school lunch for

Vitamin A resource instead of carrot, materials of Caribbean paste for bottling product, and materials of Vitamin A fortification foods.

Another new type is non-sweet sweet potato. Usually, steam-cooked potatoes tastes sweet, because a large amount of maltose is produced as a result of hydrolysis of starch caused by β-amylase activity. The new sweet potato will not be too sweet because its maltose production is inhibited by the lack of β-amylase activity.

A new non-sweet type cultivar 'Satsumahikari' was selected from a number of breeding materials at the Nat'l Kyushu Agr. Exp. Stn. in 1987. 'Satsumahikari' will be utilized as raw materials for frozen French potato, dried flake and dried granule. Of them, frozen French potato made by non-sweet sweet potato has the advantage of longer length than that made by Irish potato, and dried granule will be used as cheap raw materials of specific foods for infant and aged persons.

5) World network

The Centro Internacional de la Papa (CIP) in Peru is a mandatory institute for collection and preservation of sweet potato genetic resources in the worldwide network under the CGIAR System, and the Asian Vegetable Research Development Center (AVRDC) in Taiwan is expected to support the CIP's activity in this field. Genetic resources preserved at the International Institute of Tropical Agriculture (IITA) in Nigeria were already transferred to CIP by *in vitro* culture, and famous YEN's collection which was collected from the Pan-Pacific region, the 2nd gene center of sweet potatoes, is being preserved in Japan together with CIP and AVRDC.

3. Cassava

Cassava (*Manihot esculenta*) is considered to be originated at upstream region of the River Amazon, and is planted widely in the South America as an important crop for inhabitants. After the discovery of America by COLUMBUS, cassava was introduced into Africa, and became popular as a main staple food for people living there. Cassava is also planted widely in the South-eastern Asia, but it is not cultivated in Japan.

Cassava is mostly cultivated by small farmers who input no capitals in their farms for fertilizing and for controlling diseases and insect pests. Resistance to diseases and insect pests, therefore, is main objectives in collecting germplasm including wild relatives. Especially, resistance to virus diseases and bacterial diseases, and resistance to mite and mealy bug are important characters for collection.

IITA's new cultivar 'TMS4(2)1425' which was developed from three backcrossing including wild relative species *M. glaziovii* as a donor and cultivars as recurrent parents has resistance to virus diseases and bacterial diseases, and has low cyanamide contents. Furthermore, 'TMS4(2)1425' has a gene for apomixis of the wild relative which is expected to open new era of cassava breeding. When 'TMS4(2)1425' is used as a maternal parent for cross, next generation derived from the cross develops only clone plants which have the same genotype of mother plant.

Under the CGIAR system, CIP is the mandatory institute for collecting and preserving cassava germplasm including wild relatives and for breeding for the South America and South-eastern Asia, and IITA is the institute responsible for breeding for Africa.

4. Yam

Yam includes several species which are considered to be originated at different regions in the world. For example, *Dioscorea alata* and *D. esculenta* are Asian origin, *D. rotundata* is African origin, and *D. trifida* is tropical American origin, and these yams belong to the same genus as Japanese indigenous crop Naga-imo (Chinese yam, *D. opposita*) and Jinenjo (*D. japonica*).

So far, breeding of yam is still in a primitive stage, because selection of elite clone was the only way to improve yam cultivars. Recently, cross breeding was started at IITA, and it produced wide genetic variation suggesting rapid progress in near future. IITA is the mandatory institute for collecting, preserving and breeding of yam under the CGIAR system, and *in vitro* culture of virus free clone is being performed for preserving yam germplasms at IITA.

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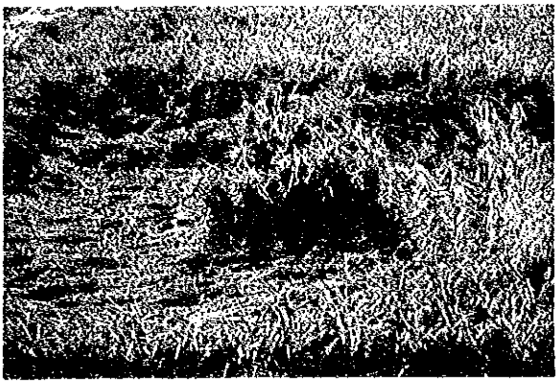

Photo 1. A brown plant hopper resistant line in mid of susceptible rice cultivar. The resistance was incorporated from an exotic germplasm by backcrossing. (C. KANEDA)

Photo 2. Field screening of resistance for barley yellow mosaic virus. Resistant strains show healthy growth on a diseased field, while susceptible ones turn yellow and stunted. (Tochigi Pref. Agr. Exp. Stn.)

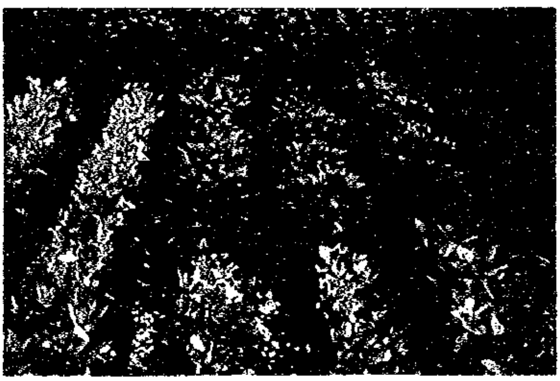

Photo 3. Soybean cyst nematode-resistant variety 'Nemashirazu' (center-right), shows healthy growth on a diseased field, but a susceptible local variety (left) turns yellow. (K. HASHIMOTO)

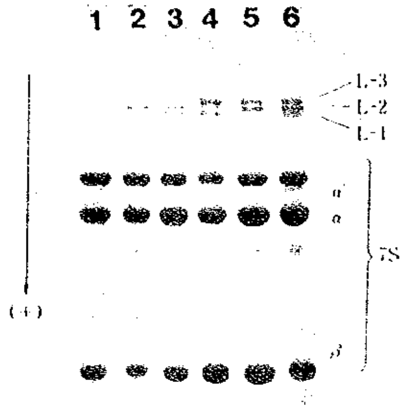

Photo 4. Detection of lipoxygenase-deficient lines of soybean by SDS-PAGE. No.1-No.5 identified from germplasms lack one or two bands as compared with the standard (No.6). (K. KITAMURA)

Photo 5. High yielding sweetpotato of multiple resistance, 'Minamiyutaka' was developed through wide crosses. (Y.UMEMURA)

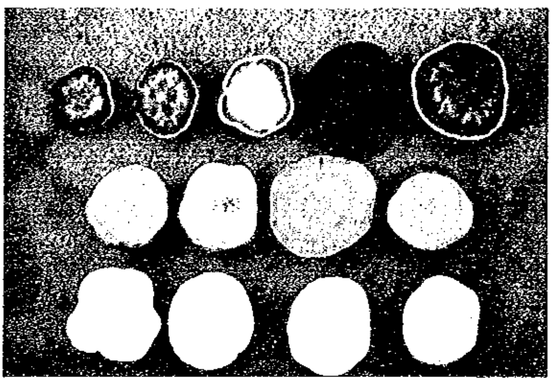

Photo 6. Fresh color variations in sweetpotato: Some are noted for high carotene contents, while others show purple fresh. Those with normal color are shown in lower row. (Y.UMEMURA)

Fruit Trees

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CONTENTS

1. Introduction

Japan is very small in terms of its area over four main islands, Hokkaido, Honshu, Shikoku and Kyushu, but ranges very long from north to south. In its northern part, it is very cold in long winter season, while its southern part is in subtropical climate. Therefore, many kinds of fruit tree have been cultivated now in Japan. Out of the fruit trees, important ones such as apple (*Malus pumila* MILL. var. *domestica* SCHNEID.), peach (*Prunus persica* (L.) BATSCH), sweet cherry (*Prunus avium* L.), European pear (*Pyrus communis* L.), etc. were introduced from foreign countries about 120 years ago.

Indigenous genetic resources are Japanese pear (*Pyrus pyrifolia* NAKAI var. *culta* NAKAI; previously designated as *P. serotina* RHED. var. *culta* RHED.), Japanese chestnut (*Castanea crenata* SIEB. *et* ZUCC.), persimmon (*Diospyros kaki* L. f.), and etc. The origins of many cultivated fruits are localized in foreign countries as shown in Fig. 1. The introduction of fruit genetic resources is very much important for fruit tree improvement. Therefore, many cultivars and wild types of several fruit trees have been introduced from many foreign countries up to date. Many new cultivars have been bred by using the introduced cultivars. And, the wild types are also going to be used as breeding materials.

2. Utilization for rootstock

In many fruit trees, the cultivars with good fruit characters are grafted on rootstocks. Therefore, objectives in the rootstock breeding are different from those for cultivars for fruits. Seedlings of wild types have been used for the rootstock in apple, Japanese pear, peach, etc. Recently, the characters such as dwarfness, cutting ability, resistance to diseases or pests in soil have become important objectives in the breeding of rootstock.

1) Peach

The replant failure of peach and plum by soil sickness is very serious problem in the old orchards in Japan. One reason of the soil sickness seems to be several kinds of nematode. Therefore, genetic resources for the resistance to one of nematodes, *Meloidogyne incognita* var. *acrita* CHITWOOD were surveyed by artificial inoculation, and divided into three groups, "Immune", "Resistant" and "Susceptible" (YOSHIDA 1981a). Most of cultivars cultivated in Japan were grouped in "Susceptible", however, clones with "Immune" or "Resistant" were observed in ornamental cultivars and wild types (Table 1).

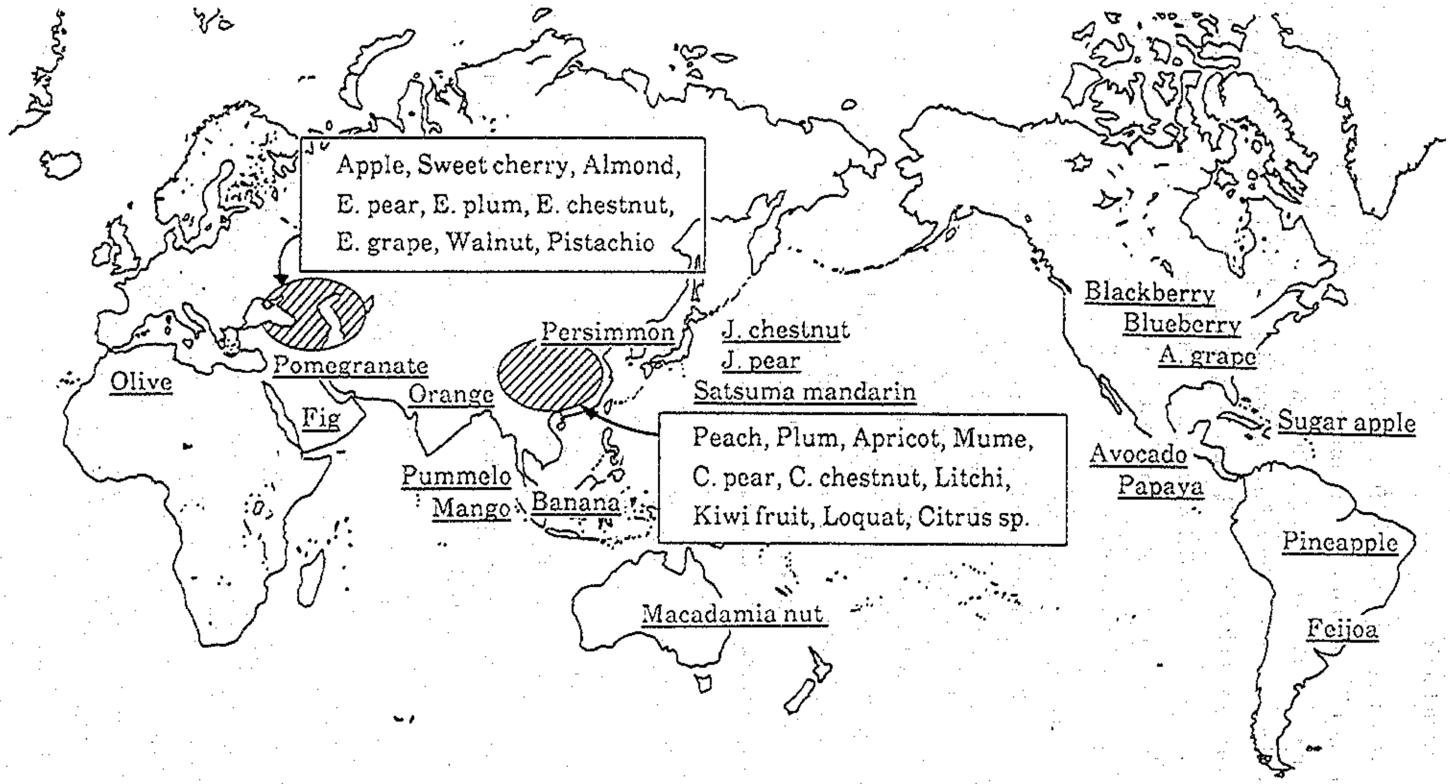

Fig. 1 Origins of cultivating fruits

Table 1 Root-knot nematode (*M. incognita*) resistance in wild types, cultivar for fruit and ornamental peach. (Modified from YOSHIDA 1981a)

Clone	Evaluation[1]	Clone	Evaluation[1]
[Wild type in Japan]		[Cultivar for fruit]	
Nagano (early)	S	Shanghai	S
Nagano (late)	S	Okitsu[2]	S
Ohatsumomo	I	Table peach[2]	S
Noto-2	I	Canning peach[2]	S
Noto-3	S	Nectarine	S
Noto-6	S	[Ornamental]	
Noto-8	I	Akame	S
Noto-9	S	Akashidare	I
Chichibu-1	S	Genpeishidare	I
Chichibu-4	I	Genpeishidaremomo-1	S
Akita-1	S	Genpeishidaremomo-2	S
Akita-2	S	Sagamishidare	I
Okinawa-1	I	Shiroshidare	I
[Rootstocks or wild types		Zansetsu shidare	I
in foreign country]		Houkimomo	I
Kutao-1 (China)	I	Genpei	I
Kutao-5 (China)	I	Kanhitou	R
Kutao-7 (China)	I	Kikumomo	I
Thai (Thailand)	R	Nakatejiro	I
Argentina (Argentine)	S	Juseitou (single, pink)	I
Harrow Blood (USA)	S	Juseitou (double, pink)	I
Lovell (USA)	S	Juseitou (double, red)	I
Nemaguard (USA)	R	Juseitou (double, white)	I
Lot 303 (USA)	I		
Rancho Redleaf (USA)	R		

Note: The seedlings from these clones were tested by the artificial inoculation.

1) I : Immune, R : Resistant, S : Susceptible.

2) Tested at the fields containing *M. incognita*, *M. mali*, etc.

The inheritance of resistant to the nematodes, *M. javanica* (TREUB) CHITWOOD, besides *M. incognita* was investigated (YOSHIDA and SEIKE 1981). The resistance was controlled by a single dominant gene in both nematodes. Furthermore, several resistant clones were selected for the rootstock of peach through the investigation (YOSHIDA 1981), and have been tested for rootstock characters.

Dwarf rootstocks have been studied using several clones of *Prunus japonica* THUNB., *P. tomentosa* THUNB., *P. cerasifera* EHRH., etc. (MURASE *et al.* 1986, SUZUKI *et al.* 1986). The cultivars of peach grafted on some clones of *P. japonica* and *P. tomentosa* were apparently dwarf compared with those on the seedlings of *P. persica* (Table 2). Some clones of the dwarf rootstock or having the resistance to nematodes have practically been used for the rootstock of peach.

Table 2 Effect of rootstocks on growth of peach trees in third season in the orchard (5-year-old). (Modified from MURASE et *al.* 1986)

Cultivar	Rootstock	Shoot length (cm)	Trunk circumference (cm)	Tree size	
				Width (cm)	Height[1] (cm)
Hakuhou	*P. tomentosa* (A)[2]	14.3	16.5	173	350
	P. japonica (A)	15.2	19.1	243	350
	P. japonica (B)	16.4	20.1	203	350
	P. persica[3]	32.8	25.3	400	350
Hakutou	*P. tomentosa* (B)	13.6	11.4	133	190
	P. japonica (B)	16.2	18.8	243	243
	P. persica[3]	35.3	26.1	357	350

Note: 1) Central leader trees, and height of trees was controlled by pruning.
2) (A) was infected by CLSV, (B) was not infected by CLSV.
3) Clone name is 'Juseitou'.

2) Apple

Some clones in *Malus prunifolia* BORKH which are able to be vegetatively propagated have been used for the rootstock since about 100 years ago in Japan. Recently, the utilization of dwarf rootstocks such as 'M9', 'M26' and 'MM106' selected in England has gradually increased, because the dwarf rootstocks are superior to others in labor-saving, fruit quality and in yield ability. However, they lack cutting ability, although some clones of *M. prunifolia* have a high cutting ability. Accordingly, the selection of rootstocks with both dwarfness and cutting ability has been developed at the Morioka Branch, Fruit Tree Research Station (FTRS). Now, about 10 clones with such characters are selected by crossing among 'M9', 'M26' and *M. prunifolia*, and the new clones have been in trials for practical use in several regions.

Furthermore, 'M26' and 'MM 106' which have been diffused for the dwarf rootstock in many countries are susceptible to soil sickness (*Phytophthora cambivora* (PETRI) BUIS., *P. cactorum* (LEB. *et* CHON) SCHROET.). The artificial inoculation of these spores to many wild species of apple was performed, and several resistant clones were selected at the Morioka Branch, FTRS. These clones will be taken into the breeding programs of rootstocks in future.

3) Japanese pear

A physiological disorder, "yuzuhada" is caused by water stress in fruit of 'Nijisseiki' which is one of important cultivars. The phenomenon occasionally occurs in water-deficient fruit which results from soil desiccation (HAYASHI and WAKISAKA 1956) or the deterioration of root activity under an excess of soil humidity (HAYASHI and TANABE 1991). The "yuzuhada" occurs especially in the rootstock of *Pyrus pyrifolia* which has been used as rootstock since old times. Recently, it appeared that this incidence was reduced when some clones of *P. betulaefolia* BUNGE were used for the rootstock. HAYASHI and TANABE (1991) reported that 'Aokei' out of several clones of *P. betulaefolia* has showed a high activity in the root and hardly caused "yuzuhada" under an excess of soil humidity. To use this clone for the rootstock of Japanese pear is considered promising.

3. Utilization for cultivars

In introduced fruit trees such as apple, peach and sweet cherry, many cultivars bred in foreign countries had been directly used for cultivation especially from early Meiji to early Showa Era. Thereafter, many cultivars have been gradually bred by using those introduced materials. Now, apple cultivars such as 'Fuji', 'Tsugaru', 'Ourin', etc. which were bred in Japan, occupy about 70% of the production (Table 3).

Table 3 Main apple cultivars cultivated in Japan.

Cultivars	Ripeness	Occupation[1] rate (%)	Cross combination			Country
Fuji	Early Nov	42.3	Ralls Janet	×	Delicious	Japan
Starking Delicious	Early Oct	13.9		–		USA
Tsugaru	Mid. Sep	13.4	Golden Delicious	×	–	Japan
Ourin	Late Oct	6.3	Golden Delicious	×	Indo	Japan
Jonagold	Mid. Oct	4.0	Golden Delicious	×	Jonathan	USA
Mutsu	Late Oct	3.3	Golden Delicious	×	Indo	Japan
Sensyuu	Late Sep	3.1	Toukou	×	Fuji	Japan
Jonathan	Early Oct	2.4		–		USA
Hokuto	Mid. Oct	1.6	Fuji	×	Mutsu	Japan
Golden Delicious	Early Oct	1.2		–		USA

Note: [1] The rate was calculated by the productions in 1988.

On the other hand, in fruit trees originated in our country such as Japanese pear, persimmon, etc., the clones (local cultivars) with good fruit quality have been collected from planted areas since about 100 years ago. Several excellent clones such as 'Fuyuu', 'Jirou', 'Hiratanenashi', etc. in Persimmon, 'Kouzou', 'Choujuurou', etc. in Japanese pear, 'Ginyose', "Tanba', etc. in Japanese chestnut, 'Unshiu' (Satsuma mandarin, *Citrus unshiu* MARC.), 'Hassaku' (*C. hassaku* Hor. ex TANAKA), etc. in *Citrus* were selected. And, new cultivars, 'Suruga', 'Izu', 'Youhou', etc. in persimmon, 'Kousui', 'Housui','Chikusui' etc. in Japanese pear, 'Tsukuba', "Tanzawa', 'Kunimi', etc. in Japanese chestnut, 'Kiyomi', 'Hayasaki', 'Nankou', etc. in *Citrus* have been bred by using these clones.

When wild types are used as the materials of cross breeding for the improvement of cultivars, we need a long period because it takes many years from crossing to fruit set in many fruit trees such as apple, pear, *Citrus*, persimmon, etc. Therefore, such instance of breeding as incorporating excellent characters of wild types into cultivars are not so many in the world.

1) Apple

In an international scale, *Malus floribunda* SIEB. has been used for breeding of resistant cultivars to scab disease (*Venturia inaequalis* (COOKE) WINTER) which is one of the most serious diseases in the northern part of the world. The resistance to the disease is controlled by a single dominant gene in *M. floribunda* clone No.821 which was originated in Japan, although the resistance to the disease is controlled by polygenes in commercial cultivars. The breeding program using *M. floribunda* - 821 has been developed in USA and the other countries, several cultivars such as 'Prima' (DAYTON 1970), 'Priscilla' (WILLIAMS 1972), 'Primicia' (DENARDI *et al.* 1988 ; Fig. 2), etc. have been bred through many years from the first crossing between 'Rome Beauty' and *M. floribunda* - 821.

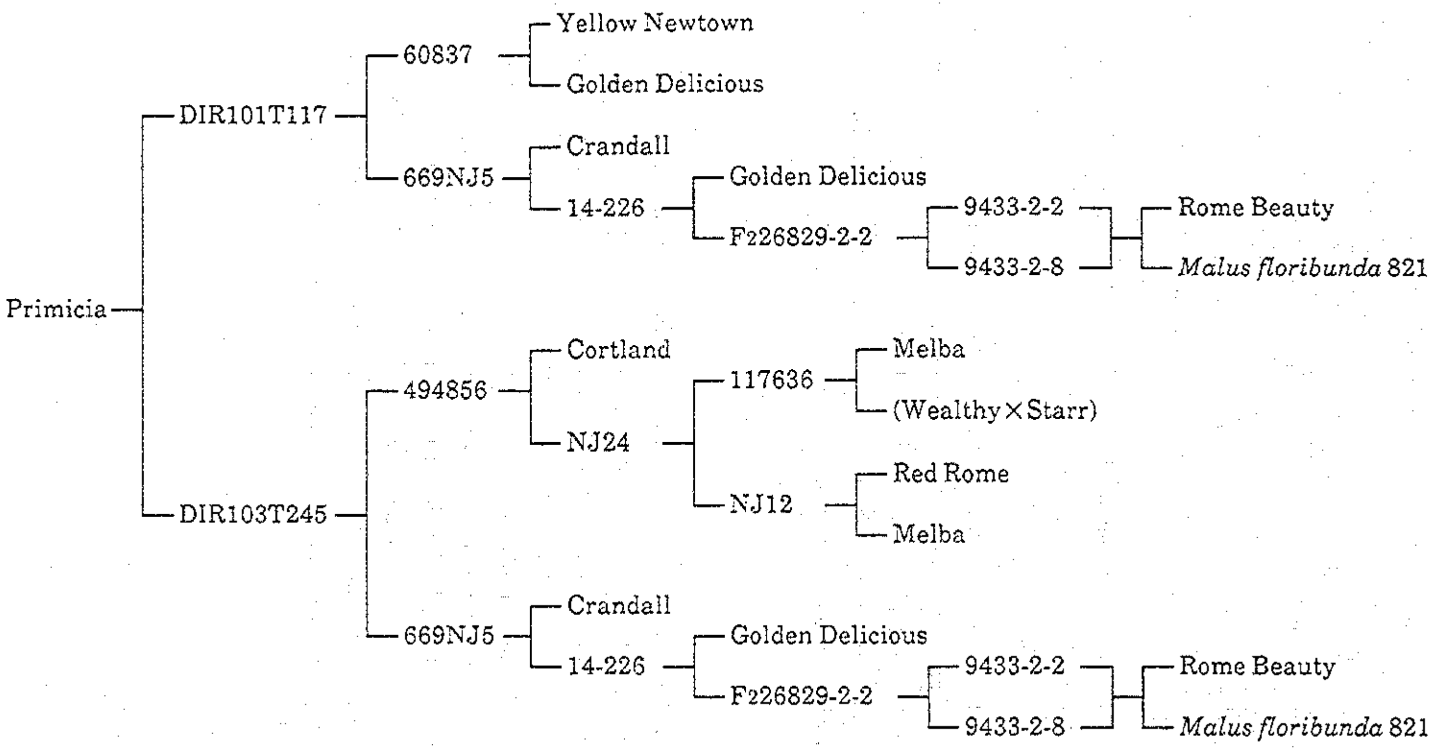

Fig. 2 'Primicia', a resistant cultivar to apple scab disease (*Venturia inaequalis* (COOKE) WINTER) by using a wild type, *Malus floribunda* SIEB. (DENARDI *et al.* 1988)

Until about 20 years ago, the scab disease had not been so serious in Japan. However, the damage by the disease has gradually increased especially in the northern part of Japan. Therefore, a breeding program for resistant cultivars to the disease has been planned by using the resistant cultivars such as 'Prima', 'Priscilla', 'Primicia', etc.

Concerning with branching habit of trees, an experiment to take the weeping character of a crab apple, 'Red Jade' into commercial cultivars has been performed at the Morioka Branch, FTRS. Such clones with branches at 60 - 90° angles from the trunk were obtained in F_1 generations, although the fruit size was intermediate between 'Red Jade' and commercial cultivars. The selected clones in F_1 have been crossed still more to commercial cultivars. The progenies must be crossed repeatedly to commercial cultivars until a fruit as big as commercial cultivars is obtained.

2) Japanese pear

Black spot disease (Japanese pear pathotype of *Alternaria alternata* (FR.) KEISLER) is one of the most serious diseases. Therefore, growers have prevented the occurrence of the disease by wrapping the fruit with a paper bag and by frequent spray of fungicides in the cultivation of susceptible cultivars such as 'Nijisseiki'. Genetic resources were surveyed by inoculation of the spores, and divided into resistant or susceptible group (KOZAKI 1973). The susceptibility to this disease is controlled by a single dominant gene (KOZAKI 1973). Thereafter, the resistant cultivars have been mainly used for breeding materials, and many resistant cultivars with good fruit quality were bred in FTRS. The chemical structure of host specific toxins released from the pathogen was determined (NAKASHIMA *et al.* 1982, NAKASHIMA *et al.* 1985). And, a method of selecting resistant clones was developed by using the toxin (SANADA 1988). It seems that the susceptible cultivars with good fruit quality are also able to be used for the parents of cross breeding.

Scab disease (*Venturia nashicola* TANAKA *et* YAMAMOTO) in Japanese pear is also a serious one. The resistant cultivar is not found among the commercial cultivars. Recently, some resistant clones including *P. aromatica* KIKUCHI *et* NAKAI were selected among many genetic resources by inoculation of the spores (ABE *et al.* 1990). Now, the genetic analysis has been performed in FTRS. If the resistance is controlled by a single dominant gene, such new cultivars as resistant to the disease will be bred by using these resistant materials within a short period.

3) Japanese chestnut

The cross breeding of chestnut was started in 1947 at the Horticultural Research Station (the preceding one for FTRS) for the improvement of productivity, quality, etc. However, the chestnut gall wasp (*Dryocosmus kuriphilus* YASUMATSU) was observed in Okayama Prefecture for the first time in 1941, and the insect spread rapidly over various regions (SHIMURA 1972a). They lay their eggs in dormant buds on current branches at June - July, and these buds develop to galls in next spring. Thus, they cause a great damage for the chestnut trees. Therefore, the breeding of cultivars with resistance to the insect became one of the important objectives (SHIMURA 1972a).

In field observation, some cultivars with resistance to the insect were found among genetic resources of chestnut. They were divided into two groups, the resistant and the susceptible. The cross breeding has been developed by using these resistant cultivars, and a high percentage of resistant seedlings was obtained from hybrids between resistant and susceptible cultivars (KAJIURA 1955; Table 4). The resistant cultivars, 'Tanzawa', 'Ibuki', 'Tsukuba' and 'Ishizuchi' were released from the breeding program.

Table 4 Segregation of resistance to the chestnut gall wasp in hybrid seedlings derived from various crosses. (KAJIURA 1955)

Combination[1]	Hybrid seedlings	Resistant seedlings	Non-resistant seedlings	Percentage of non-resistant seedlings
A	86	86	0	0.0
B	258	257	1	0.4
C	170	148	22	12.9
D	302	231	71	23.5
E	170	38	132	77.6

Note: 1) A: 'Ginyose' × Resistant cultivars except 'Ginyose'
B: 'Ginyose' × Non-resistant cultivars
C: Resistant cultivars except 'Ginyose' × Resistant cultivars except 'Ginyose'
D: Resistant cultivars except 'Ginyose' × Non-resistant cultivars
E: Non-resistant cultivars × Non-resistant cultivars

However, these resistant cultivars released from the breeding program have recently been infected by another strain of the insect. This strain is also differentiated from the previous strain in isozyme analysis besides the difference of infection (SHIMURA 1972b).

On the other hand, several kinds of parasitoid which attack the chestnut gall wasp were reported. Out of these parasitoids, *Torymus sinensis* KAMIJO which was introduced from China is one of important parasitoids. The gall formation ratio of chestnut buds steadily decreased after the release of *T. sinensis* in the FTRS's field (MORIYA *et al.* 1989). Therefore, the investigation of the parasitoids besides the breeding of resistant cultivars have been performed for the protection against the chestnut gall wasp.

4. Utilization of wild types for cultivation

The fruits of wild fruit trees, which grow in wild plains or mountains, have been used for fresh fruits or the processing materials in limited locations. They are especially in *Actinidia arguta* PLANCH. *et* MIQ., *Vitis coignetiae* PULLIAT., *Akebia trifoliata* KOIDZ., *Vaccinium uliginosum* L., *Juglans sieboldiana* MAXIM., *J. subcordiformis* DODE., *Lonicera caerulea* L. spp. *edulis* HULTEN var. *emphyllocalyx* NAKAI (haskaop), *Myrica rubra* SIEB. *et* ZUCC. (wax myrtle), *Aesculus turbinata* BLUME (horse chestnut). In the wild fruit trees such as haskaop, wax myrtle etc., the clones selected from wild plains have been cultivated.

1) Haskaop

This fruit tree has grown in northern part of Japan. The fruit was used for preservative food in old time. The trees which grow in wild plains bear many small black-blue fruits of 0.5 - 1.0g in weight. Farmers have collected the fruit and used them for jam, cakes and liqueur. Recently, several clones with good fruit quality were collected from the wild plains. Out of these clones, the promising clones was named as 'Yuufutsu' after their characters were examined at the Hokkaido Central Agricultural Experiment Station. Moreover, the cross breeding has been developed by using these selected clones. In CIS (former USSR), some cultivars are also selected among the collections of *Lonicera* sp. Therefore, these cultivars and wild types must be introduced from foreign countries, and more excellent cultivars should be bred by using such materials.

2) Wax myrtle

This fruit tree which is ever green and monoecious, has grown in the southern part of Japan, bearing many small red fruits with the same size as sweet cherry. Several colonies are now preserved in wild state, farmers in these regions have collected clones with good fruit quality, and planted in their gardens or orchards for the materials of liqueur, juice and jam from old times. Some excellent clones were named as 'Kamezou', 'Kougyoku' etc. out of the selected ones by the farmers, and have been sold by nursery companies, although the cross breeding was not yet performed. These cultivars have been commercially planted in limited regions. Moreover, recently, genetic resources with good fruit quality were also collected by the exploration in the several colonies (KAJIURA *et al.* 1986). In China, the dwarf type or clones with big fruit size were found. The cross breeding must be developed by using the selected clones in future.

3) Walnut

Utilization of the wild types of walnut, *Juglans sieboldiana* MAXIM., and *J. subcordiformis* DODE. is practically limited, because the shell is very hard, and the embryo is not so large, although the nut quality is good. However, the smooth cracking types of shell were recently found among wild clones, these clones were released as "Tsuguekei' and 'Warau' in *J. sieboldiana*, and 'Karasu kurumi' in *J.subcordiformis*. Furthermore, these wild types were used as breeding materials for the cold or frost resistance cultivars in Germany.

4) *Actinidia arguta*

Actinidia arguta PLANCH. *et* MIQ. with several different characters has grown in wild plains or mountains in Japan. The fruit has a taste very similar to kiwi fruit (*A. deliciosa* LIANG *et* FERGUSON) and hairless type, although the fruit size is very small. Therefore, they were used as the materials for cross breeding in the improvement of kiwi fruit. The hairless clone which was selected among these seedlings has been released as 'Shinzan'.

5. Conclusion

As has been stated, useful genes which did not exist in cultivars have been found in wild types. The genetic diversity that we have so far used for the cultivation seems to be much limited. Therefore, we must extensively collect wild types in wild plains or mountains in the world, especially in original places for each fruit tree. Although wild types have gradually been used for the improvement of cultivated fruit trees, more actively than before, we must utilize genetic resources especially for the improvement of resistance to diseases and pests, tolerance to environmental conditions and of tree habits including dwarfness and compactness, after analyzing the performance and genetics of the characters.

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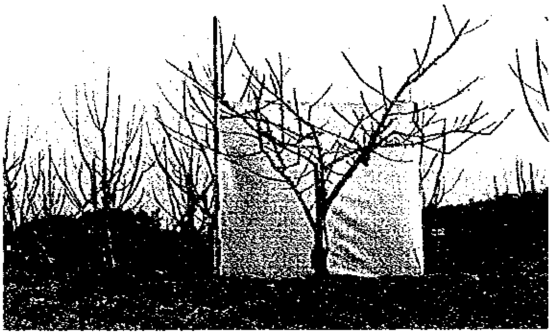

Photo 7. Five-year-old tree of 'Hakutou' grafted on *Prunus japonica* after four growing seasons. (K. SUZUKI *et al.*)

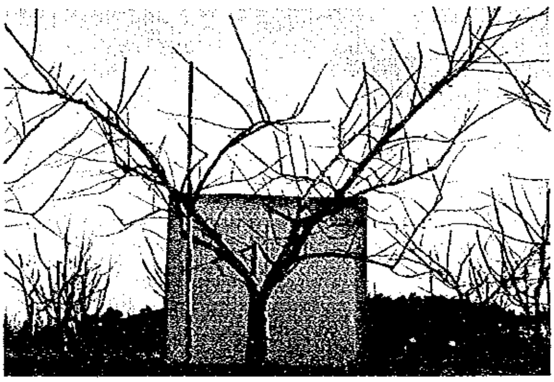

Photo 8. Five-year-old tree of 'Hakutou' grafted on *Prunus persica* ('Juseitou') after four growing seasons. (K. SUZUKI *et al.*)

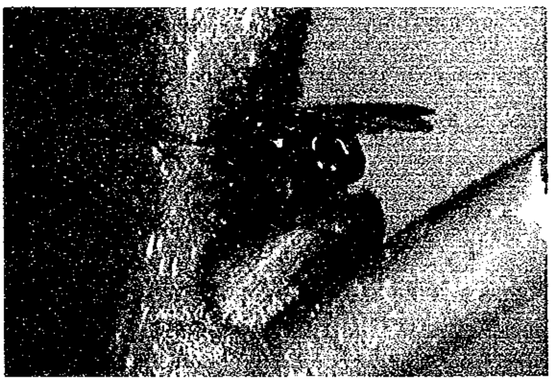

Photo 9. *Dryocosmus kuriphilus* ovipositing on a bud of chestnut tree. (S. MORIYA)

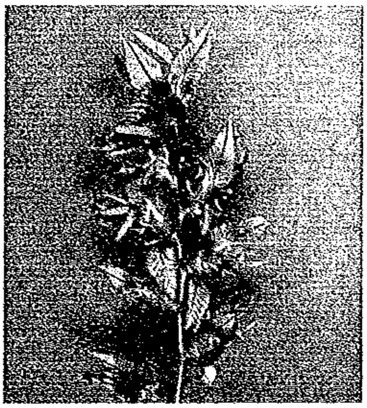

Photo 10. Swelled galls of chestnut's bud infested by *Dryocosmus kuriphilus*. (S. MORIYA)

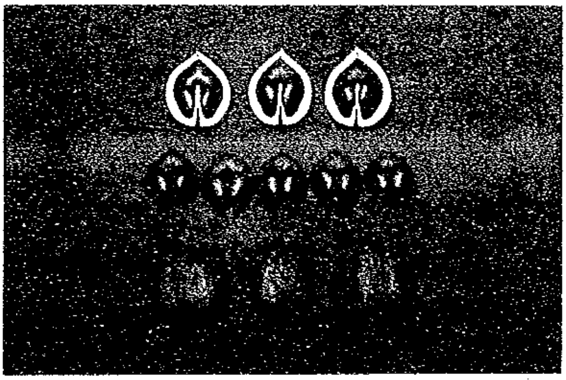

Photo 11. 'Tsuguekei', a new cultivar of *Jugrans sieboldiana*. (KOMACHIEN Co., Ltd.)

Photo 12. 'Yuufutsu', a new cultivar of *Lonicera caerulea* var. *emphllocalyx* (Haskaop).
(S. TANAKA)

Vegetables

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CONTENTS

1. Vegetables in Japan

1). Introduction of vegetables

A total number of vegetable crops which are planted and marketed reaches about 130 species of 30 families at present. Of them, only a few are native to Japan, and do not have much influence to our daily life. Most of the vegetable crops in Japan shown in Table 1, therefore, are plant genetic resources introduced for the past centuries.

Edible wild plants gathered from natural vegetation were utilized as a human food from ancient times. Cultivation of vegetables in Japan is considered to be initiated during the Yayoi era (the 2nd century B.C. to the 3rd century A.D.) when ancestors of Japanese settled for rice farming. Judging from archaeological findings and historical documents, several kinds of vegetables may have been introduced into Japan during Yayoi era.

Before Kamakura era (the 13th century), utilization of cultivated vegetables was limited to those people in upper societies or in peerage, while common people used to consume edible wild plants gathered from natural vegetation.

In Japan, edible wild plants from mountainous area were called as San-sai (vegetables from mountains), those from natural fields were called as Ya-sai (vegetables from natural fields), and edible plants cultivated by farmers were called So-sai (vegetables from farmers' fields).

Routes of introduction of the most alien vegetables are not clear yet. As cultural interchange with Korean Peninsula and Mainland China became closer from Nara era to Hei-an era (the 8th to the 12th century), some vegetables which were originated not only from these areas but also from Middle Asia, Near East and Europe were introduced into Japan through this route. Then, production of vegetables increased with development of city markets after Muromachi era (the 15th to the 16th century), and became a small industry by farmers with family garden in suburbs.

Since Muromachi era, cultural interchange with Europe was initiated by using ocean ships, and some vegetables of European origin were introduced directly from Europe into Japan as new plant genetic resources together with vegetables originated from the Continent of America.

Table 1 Vegetables in Japan.

	Main kinds	Common kinds	Special kinds	Regional kinds	
Originated from Japan		Chinese yam	Water dropwort Japanese hornwort *Cirsium dipsacolepis* Scallion Wasabi Chinese pepper Udo salad Japanese butterbur Bracken *Osmunda japonica*	Water chestnut *Glehnia littoralis* Water pepper New Zealand spinach Edible amaranthus *Allium schoenoprasum* Lily Water shield *Aralia elata* *Zizania latifolia* *Angelica keskei* Curled mallow Chieve Salt mallow	
	0	1	10	14	25
Introduction before Meiji Revolution	Radish Cucumber Watermelon Pumpkin & squash Garden pea Broad bean Snap bean Soy bean Egg plant Carrot Lettuce Edible burdock Welsh onion Spinach Turnip Taro	Oriental melon Oriental pickling melon Salt green Hot pepper Leaf mustard Garland chrysanthemum Garlic Chinese chives Ginger Lotus Bamboo	Wax gourd Bottle gourd Asparagus bean Swiss chard Arrowhead *Allium fistulosum* var. *caespitosum* *Zingiber mioga*	Sponge gourd Balsam pear Hyacinth bean Sword bean Two leaved vetch Malabar spinach Edible chrysanthemum Two coloured gynura Chinese artichoke Bottle gourd	
	16	11	7	10	44

	Main kinds	Common kinds	Special kinds	Regional kinds	
Introduction after Meiji Revolution	Melon Tomato Sweet pepper Cabbage Cauliflower Sprouting broccoli Chinese cabbage Onion Sweet corn Asparagus Strawberry	Parsley Celery	Brussel sprouts Okura	Chayote Cape gooseberry Scarlet runner Lima bean Mung bean Yokohama bean Yam bean Kale *Brassica oleracea* var. *alboglabra* Rutabaga Napus Kohlrabi Parsnip Celeriac Endive Chicory Coriander Salsify Artichoke Leak Table beet Sage Mint Swamp cabbage *Allium fistulosum* var. *viviparum* Horse radish Watercress Rhubarb Jerusalem artichoke *Cacalia delphiniiforia* *Brassica* × *napus* hort.	
	11	2	2	31	46
Grand Total	27	14	19	55	115

Although Japan closed the country door to all foreigners in Edo era (the 17th to the 19th century), historical documents indicate that the most kinds of vegetables existing today were introduced into Japan during Edo era. But, only few kinds of introduced vegetables settled for practical production.

After Meiji Revolution (1868), the new government decided to introduce European culture to modernize the traditional culture. As a part of the open door policy, many kinds of European and American vegetables were introduced into Japan, and were evaluated for their adaptability at various places in Japan. Then some introduced vegetables settled, and became popular for common people within about a hundred years, but most of introduced ones were only recorded as strange vegetables or high quality vegetables at that time.

After the 2nd World War, many kinds of American and European vegetables were again introduced into Japan under the occupation of US forces. Although they failed to settle in Japan due to difference between USA and Japan in life style and preference to food, a part of the introduced vegetables are playing important roles as plant genetic resources for vegetable breeding in Japan.

2) Settlement and differentiation of vegetables

During Edo era, a considerable number of vegetables were already planted, but common people used to consume only radish, cucumber, oriental melon, oriental pickling melon and non-head-formation leaf vegetables.

(1) Radish

Radish, *Raphanus sativus*, occupied a major part of total consumption of vegetables in Edo era, and it has been the most important vegetable in Japan. Consequently, numerous radish landraces were established in respective regions in Japan. For example, some landraces expanded their harvesting time from autumn to early summer through winter and spring, though the original harvesting time of radish was limited from late autumn to early winter.

Differentiation of radish landraces in Edo era was listed by KUMAZAWA (1956) as shown in Table 2, in which prototypes of present radish cultivars were already established in about 300 years ago. In the list, an ancestor of greenish top group which is most popular with low bite at present was indicated by the name of Miyashige.

Table 2 Radish cultivars during Edo era. (KUMAZAWA 1956)

Yamato Honzou (1709)	Seikei Zusetu (1804)	Present cultivars correspondent
	Nerima	Nerima
Miyamae,Moriguchi	Miyamae, Moriguchi	Moriguchi
Owari	Miyashige	Miyashige
	Kurahashi	Shiroagari group
Ibuki, Nezumi	Ibuki, Nezumi, Karami	Karami (supposed to be escape of Ibuki)
Murasaki	Aka, Murasaki	Meyama, Benisuji
	Kageyama, Shimizu (Nerima)	Shijuunichi, Natsudaikon
Sangatsu	Sangatsu	Harufuku
Nodaikon,Hatano, Hanana, Horiiriba	Hatano	(Escape in Kantoh)
	Hosone, Nakanuki, Oronuki	Ninengo, Tokinasi
Kohone (Tsukusi)		(Escape in Northern Kyushu)
	Minohara, Tendoh	(Escape in Southern Kyushu)
Satsuma	Sakurajima, Ohsumi	Sakurajima

(2) Pumpkin and squash

Three species of pumpkin including squash, *Cucurbita moschata, C. maxima* and *C. pepo,* are planted in Japan. Of them *C. moschata* is originated from highly humid and warm areas of the Central America, and *C. maxima* is originated from low humid and cool areas of the South America. Reflecting such environmental conditions in the originated areas, *C. moschata* and *C. maxima* have been planted and differentiated into landraces in the southern Japan and the northern Japan, respectively.

C. moschata which was introduced into Japan about 400 years ago so much differentiated into many landraces that Japan is considered to be one of the secondary centers of its genetic diversity. As *C. moschata* has been so familiar to Japanese people, it is called Japanese pumpkin, while *C. maxima* is known by the name of European pumpkin because of the new introduction after Meiji era. Only a few farmers have planted *C. pepo* cultivar 'Kinshi uri' (other names are 'Namasu uri' and 'Soumen uri') for special traditional food.

Along with the trend of Europeanizing of life style in Japan, consumption of the Japanese pumpkin suited for Japanese style cooking with soy-sauce has decreased, while consumption of the European pumpkin suitable for potage and European style cooking with oil has increased. Consequently, planting area of the Japanese pumpkin suddenly decreased, and that of the European pumpkin rapidly increased. Genetic diversity of *C. moschata*, therefore, should be carefully maintained before its disappearance from the earth.

3) Changes of vegetable kinds and cultivars

The numbers of vegetables shown in Table 1 tends to increase due to introduction of new kinds of vegetables, while some kinds of vegetables which have been planted in a limited area face the serious problem of near extinction. Changes of cultivars within one kind of vegetable is progressing rapidly, and uniformity and simplifying of cultivars appear especially within major kinds of vegetable. This trend corresponded with changes of cooking method, establishment of mass production and supply systems, and planting of F_1 hybrid cultivars. Of them, planting of F_1 hybrid cultivars became popular after the late 1950's not only in major kinds but also in minor kinds owing to their uniform growth, high yield and handy management. Consequently, popularity of F_1 hybrid cultivars resulted in disappearance of valuable landraces in minor vegetables.

2. Utilization of plant genetic resources in vegetable breeding

Most of present cultivars of major vegetables in Japan become F_1 hybrid cultivars except groups of legume and chrysanthemum. As private seed companies have played an important role in developing F_1 hybrid cultivars, their breeding process and breeding materials are not clear. Description in this chapter, therefore, is limited only to breeding works conducted at public breeding stations.

1) Cabbage

Planting of head-formation cabbage, *Brassica oleracea* var. *capitata*, began in the late Edo era with an object to supply the vegetable to European people boarding on foreign vessels or living in concessions.

After Meiji Revolution, the new government introduced seeds of numerous cabbage cultivars as a part of open door policy, and planted them at various places to examine their adaptability in Japan. Only a few introductions settled in Hokkaido where cool summer was suitable for some introduced cabbage cultivars. The growth habit of cabbage was not adapted to humid and warm condition during rainy season in the most area of Japan except Hokkaido. A new planting system with seeding in autumn and harvesting in spring to early summer was established about 80 to 90 years ago, and new cultivars adapted to the new planting system were developed about 70 to 80 years ago. Besides these new cultivars, a large amount of seed of foreign cabbage cultivars possessing good agronomic traits were imported until the 2nd World War, but the import of vegetable seed was interrupted by the war. After the war, cabbage breeding in Japan made rapid progress by establishing a F_1 seed production system using self-incompatibility, and F_1 hybrid cultivars developed in Japan are now popular not only in Japan but also all over the world.

(1) Late bolting cultivars for summer seeding

One of the important breeding objectives after the war was to develop late bolting cultivars which could be harvested in March to April, because there were no cultivar possessing such a growth habit with cold tolerance in that season. Among the introduced cultivars which were provided by the USA administration during the occupation, one cultivar 'Slowbolting Flatduch' showed head-formation without bolting from March to April when seeded at early September. Based on this cultivar, Shizuoka Agr. Exp. Stn. developed a new cultivar 'Hatsuzakura' which had a nature of late bolting at summer seeding cultivation system. Cultivars 'Shizuoka Oregon', 'New Oregon' and 'Shizuoka Danish' were also developed by Shizuoka Agr. Exp. Stn. from another introduced cultivar, 'Danish Ballhead' as a basic breeding material. New late bolting cultivars for summer seeding are all based on these cultivars.

(2) Dual resistance to clubrot and wilt

A wilt disease caused by *Fusarium oxysporum* became serious problem in major cabbage producing areas in 1960's. To cope with this problem, some wilt resistant cultivars were developed by using a resistant genetic resource which was introduced from USA. Then, clubrot caused by *Plasmodiophora brassicae* became another serious problem in the same areas. Development of new cultivars with dual resistance to both wilt and clubrot, therefore, was strongly expected by farmers in these areas.

'Nagano kouhai nakate' was employed as a basic breeding material. 'Badger Market' was selected as a donor for wilt resistance which is controlled by one dominant gene. 'Bomerwaldkohl-7255' was utilized as a donor for clubrot resistance which is controlled by a recessive gene. They were selected by Nagano Hort. Exp. Stn.. As objected cultivars will be F_1 hybrids, a major emphasis in the breeding strategy was placed on strengthening clubrot resistance in both parental lines for hybrid because of recessive genetic nature of clubrot resistance. Finally, dual resistant F_1 cultivars were developed in 1983, and were released to farmers' field in the problem areas after reproduction of the parental lines for hybrid.

2) Chinese cabbage

Head-formation Chinese cabbage, *Brassica rapa* var. *pekinensis*, was introduced into Japan in the early Meiji era (1870-1880), and settled in the late Meiji era (1900-1910). Chinese cabbage cultivars in China, from where Chinese cabbage was originated, differentiated into three ecotypes, i.e. the north type, the Shangtong type and the south type. Of them, only the Shangtong type settled in Japan, having differentiated into numerous landraces in respective regions. Recently, the north type cultivars were re-introduced to examine their characters, and the south type cultivars are being employed as a breeding material to introduce their juicy character and extreme earliness.

(1) Clubrot resistance

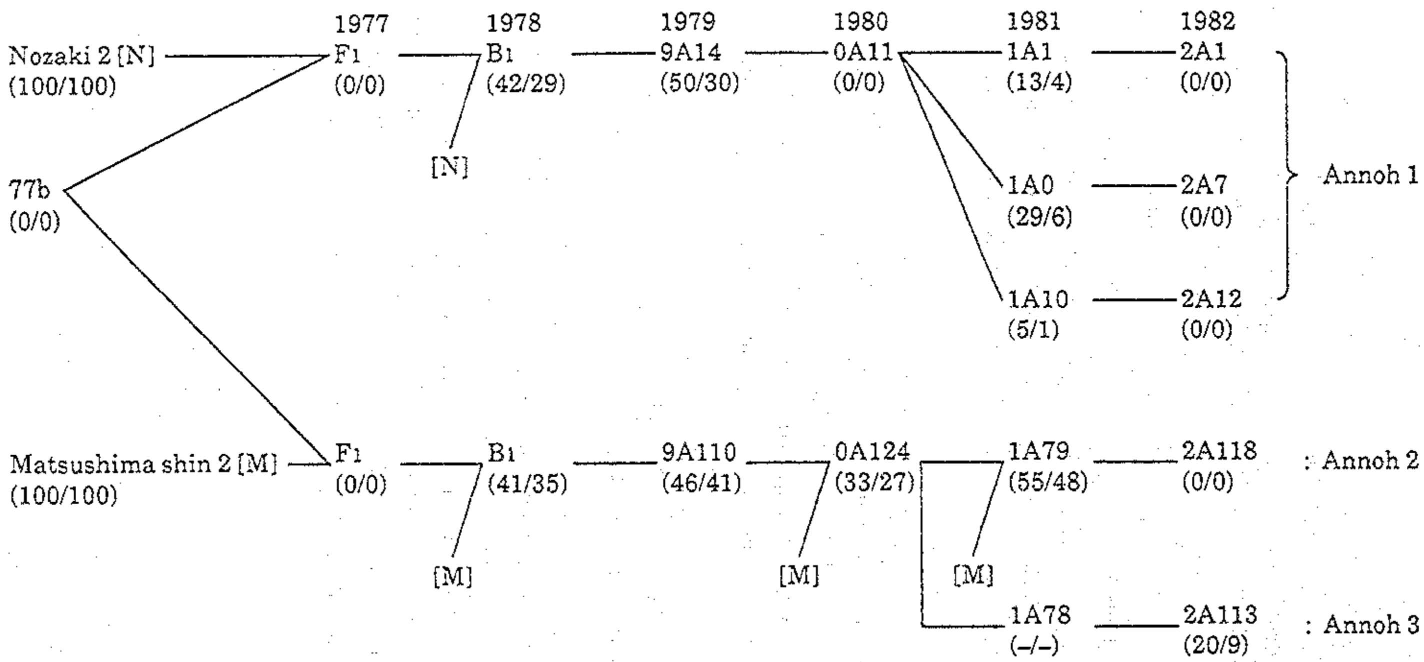
Clubrot caused by *Plasmodiophora brassicae* became serious disease for Chinese cabbage, and was epidemic in major Chinese cabbage producing areas in the late 1960's. Fungicide PCNB is effective to control clubrot, but its amount of application is limited. Farmers, therefore, expected resistant cultivars to reduce clubrot damage.

Mass screening for clubrot resistance was conducted by the Nat'l Veget. Res. Stn. with collections of Chinese cabbage, turnip (*B. rapa* var. *rapa*) and their relative leaf vegetables. None of collections from the east Asia including Japan was found to have resistance to clubrot, while some collections of turnip and forage turnip from European countries were confirmed to have resistance to clubrot.

At the first step of the breeding, turnip cultivar '77-b' without red leaf color was selected as a donor for resistance which was controlled by one dominant major gene together with some minor genes. From the crosses between '77-b' and some Chinese cabbage cultivars, five clubrot resistant lines, Chinese cabbage 'Annou 1' to 'Annou 5' were selected through the breeding procedure shown in Fig. 1.

At the second step of the breeding, the newly selected breeding lines were distributed to public and private breeding stations for further improvement of agronomic traits.

Due to differentiation of physiological races of the causal fungus, clubrot resistance introduced from '77-b' has been broken down by some physiological races existing in Hokkaido and the northern Tohoku region. Furthermore, clubrot resistant cultivars developed in Japan were reported to be completely susceptible in Germany. A new breeding strategy, therefore, should be established to cope with such differentiation of physiological races.



Note: Parenthesized are ratio of infected plant / average disease severity

Fig.1 Breeding procedure for clubrot resistant Chinese cabbage (after YOSHIKAWA 1983)

3) Radish

(1) Wilt resistance

Wilt caused by *Fusarium oxysporum* f. sp. *raphani* was epidemic in 1960's, and resulted in serious damage in major radish producing areas in Japan. Wilt incidence was aggravated by early seeding in autumn and late seeding in spring, while farmers expect to get high income by such off-season seeding cultivation.

Mass screening for wilt resistance of radish was conducted at the Nat'l Veget. Res. Stn. with a rapid testing method by an artificial inoculation and in a diseased field. As the results of screening, some genetic variations were found among cultivars belonging to the Japanese major cultivar groups, such as Mino-wase, Miyashige and Nerima group, but no genetic variation was found among cultivars belonging to Ninengo and Tokinasi group.

'Motohashi kei' from Mino-wase group, 'Aokubi miyashige soubutori' from Miyashige group and 'Kotabe' from Nerima group were selected for resistant materials by an artificial inoculation test at seedling stage and in the diseased field at adult stage. 'Radish Annou 1' (Nerima group), 'Annou 2' (Mino-wase group), 'Annou 3' and 'Annou 4' (Miyashige group) were developed after repeated selections for six to eight generations to fix wilt resistance which was assumed to be controlled by several minor genes.

4) Onion

Onion, *Allium cepa*, is a rather new vegetable which was introduced into Japan during the early Meiji era, though onion is one of the most popular vegetables at present. As leaf development and bulb expansion of onion are affected by temperature and day length, late cultivars settled in the northern Japan as a spring sown summer crop, and early cultivars settled in the southern Japan as an autumn sown winter crop.

(1) Fusarium basal rot resistance

Fusarium basal rot caused by *Fusarium oxysporum* f. sp. *cepae* became epidemic from 1960's in Hokkaido. Then, breeding of resistant cultivars was urgently required to protect onion production from the serious disease. The Nat'l Hokkaido Agr. Exp. Stn. introduced some fusarium basal rot resistant cytoplasmic male sterile lines and their maintainers from Wisconsin University, USA, and the male sterile line 'W 202' and its maintainer were selected from the introduced materials as a set of seed parent for developing F_1 hybrid cultivar with resistance to fusarium basal rot. As a pollen parent for F_1 hybrid cultivar, a selection from 'Furano landrace' which was supposed to be a derivative of 'Sapporo ki' was chosen owing to its good agronomic traits with a relatively high level of resistance to this disease. F_1 hybrid cultivar between 'W 202' and the 'Furano landrace' selection was released in 1979 by a name of 'Furanui'. Then, another F_1 hybrid cultivar 'Sekihoku' was developed at the Hokkaido Kitami Agr. Exp. Stn. from a similar cross combination.

5) Tomato

According to historical documents, tomato, *Lycopersicon esculentum*, was once introduced into Japan during Edo era. Tomato was again introduced from Europe and USA after Meiji Revolution, but it needed fifty to sixty years to become popular in Japan.

Of the introduced cultivars, some USA cultivars with pink and large size fruit were preferred by Japanese consumers owing to their sweetness, low acidity and low tomato flavor, and they have been employed as basic materials for the tomato breeding in Japan. The main reason of such choice might be due to eating style in Japan, because consumption of tomato was limited only for fresh fruit eating and not for cooking.

(1) Dual resistance to TMV and fusarium wilt

Fusarium wilt caused by newly differentiated race of *Fusarium oxysporum* f. sp. *lycopersici* was first reported in 1970's in Japan. Due to the symptom different from those caused by the existing race J_1 and J_2 of *F. oxysporum* f. sp. *lycopersici*, the causal fungus race was named as race J_3. Fusarium wilt caused by race J_3 has been epidemic in green houses in low temperature period. Existing wilt resistant cultivars against the race J_1 and J_2 are susceptible against race J_3. Mass screening for resistance to race J_3 was conducted at the Nat'l Veget. Res. Stn., and the wild relative species *Lycopersicon peruvianum* (PI 126944) was selected as a resistant genetic resource. As *L. peruvianum* was cross-incompatible with cultivated tomato, pollen of PI 126944 was irradiated before pollination, and was crossed with cultivar 'Shugyoku' at the Institute of Radiation Breeding, MAFF. An interspecific hybrid was successfully developed by this new technique, and some of its offsprings were confirmed to have resistance to race J3 and to TMV. These dual resistant individuals were employed as donor parents for breeding of resistance to race J3 and TMV at the Nat'l Veget. Res. Stn.. They were crossed repeatedly with cultivars 'Ponderosa', 'Fast' and 'Fukuju' as shown in Fig. 2. Then, "Tomato Annou 4' and 'Annou 5' were released as parental lines for developing F1 hybrid cultivars possessing resistance to race J3 and TMV, and were distributed to public and private breeding stations. Finally, 'Kagyoku' (Tomato Annou kou 1) and 'Ryuugyoku' (Tomato Annou kou 2) were developed as the first F1 cultivars with dual resistance to J3 fusarium wilt and TMV at the Nat'l Veget. Res. Stn. in 1984.

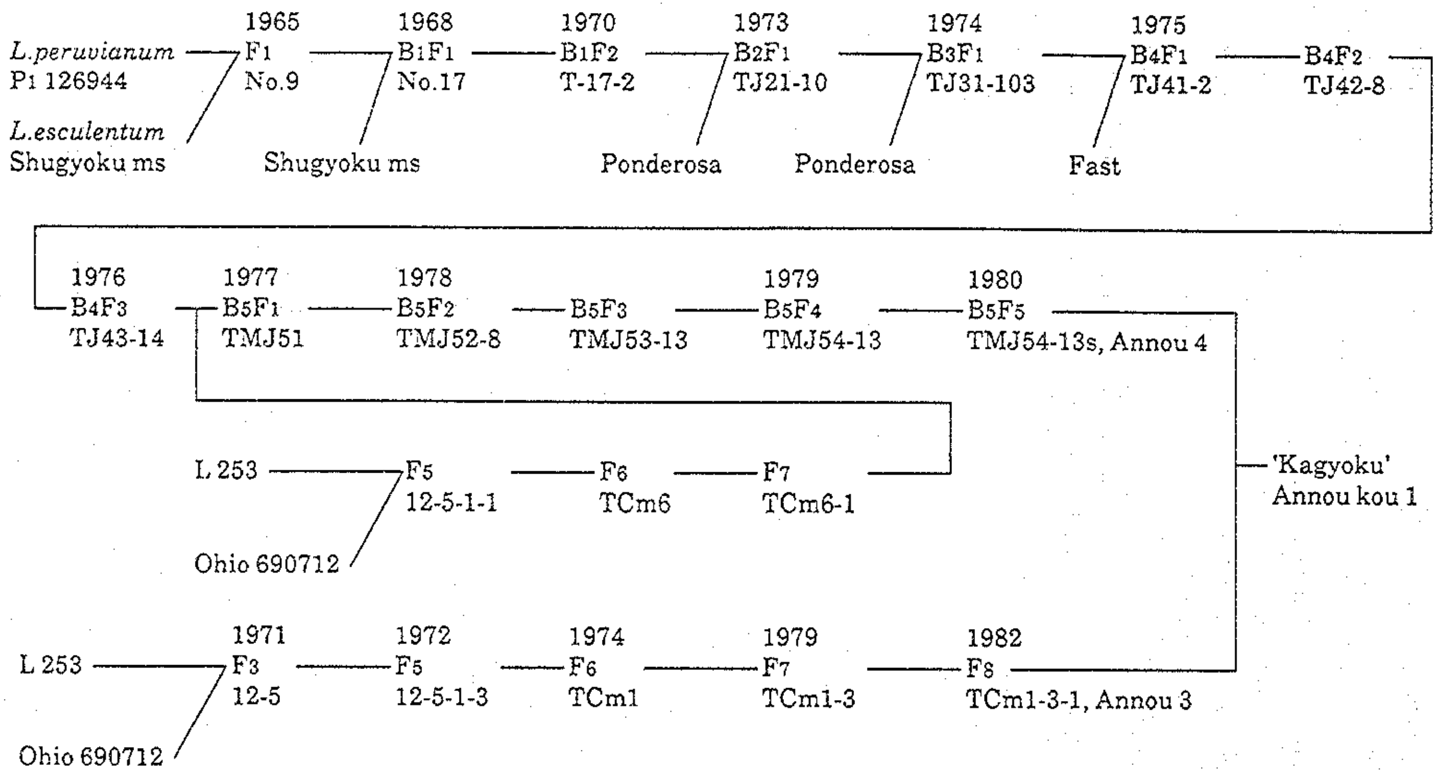


Fig.2 Breeding procedure for dual resistant tomato F_1 cultivar against fusarium wilt and TMV (after YAMAKAWA 1987)

6) Melon

Popular melon, *Cucumis melo*, was the Asian type melon (oriental melon : makuwa uri) in Japan before 1960's. After releasing a new type cultivar 'Prince melon' which was the F_1 hybrid cultivar developed in 1962 between the Asian type melon and the European cantaloupe type melon, consumption of the Asian type reduced rapidly, while melon cultivars of high quality European types with melting flesh nature were widely accepted by Japanese consumers. Consequently, new type melon cultivars adapted to new cultivation system in vinyl house became popular at present.

(1) Powdery mildew resistance

High quality European type melon has a disadvantage of susceptibility to powdery mildew caused by *Sphaerotheca fuliginea*. Mass screening for powdery mildew resistance of melon was conducted at the Nat'l Hort. Exp. Stn., and USA reticulate type cultivars 'C-68' and 'Georgea 47' were selected as resistant donors for strengthening disease resistance of European type melon. Then, 'Melon Hiratsuka 1' developed by pure line selection from 'C-68'. The powdery mildew resistance of 'C-68' was determined to be controlled by two dominant genes.

At the first step of breeding for resistance to powdery mildew, 'Melon Hiratsuka 1' was used as a parent for developing the F_1 hybrid cultivar together with an excellent quality cultivar 'Pearl', and the F_1 cultivar was released for practical production by a name of 'Sunrise' in 1969. But, 'Sunrise' was not accepted by consumers due to red flesh color and early deterioration after harvest.

(2) Multiple resistance to powdery mildew, fusarium wilt, gummy stem blight, downy mildew and cucumber mosaic virus

At the second step of breeding for disease resistance of melon, the Nat'l Veget. Res. Stn. tried to accumulate multiple disease resistance in one breeding material. Target diseases were powdery mildew, fusarium wilt, gummy stem blight, downy mildew and cucumber mosaic virus. 'Georgea 47' was selected as a resistance donor against powdery mildew and fusarium wilt, and Chinese cultivar 'Miitantin' of the Asian type melon was selected as resistance donor against gummy stem blight, downy mildew and cucumber mosaic virus. From the cross between 'Georgea 47' and 'Pearl', 'Melon Hiratsuka 3' was selected as a breeding material with powdery mildew and fusarium wilt resistance and good agronomic traits, then 'Melon Hiratsuka 3' was crossed with 'Miitantin'. As the result of this cross, 'Melon Annou 1' to 'Annou 3' were selected for parental lines with multiple resistance against five diseases, then 'Melon Annou kou 5' which is the F_1 hybrid between 'Melon Annou 1' and 'Earl's natsu kei 7' was developed as the first multiple resistant F_1 cultivar against five diseases.

(3) Slow deterioration nature of fruit

F_1 hybrid cultivars which were developed with 'Pearl' at an early stage of F_1 hybrid breeding had an advantage of stable sweetness, but had a disadvantage of tendency to early deterioration after harvest. Slow deterioration nature of fruit, therefore, was one of the important breeding objectives. Niigata Hort. Exp. Stn. succeeded in development of a cultivar 'Fukamidori' with the slow deterioration nature and stable sugar content in 1974. 'Fukamidori' is the F_1 cultivar between 'Kei 607' (green flesh selection of'Pearl'/'Rocky Ford') and 'Kei 618' (selection of 'Earl's natsu kei 2'/'Georgea 47'), and showed a possibility of developing F_1 cultivars with the slow deterioration nature.

7) Stock for fruit vegetables

Grafting is widely used to protect fruit vegetables from soil born diseases and to accelerate early growth under low temperature condition. Suitable stock for grafting has to have following natures; ① high graft-compatibility without any inferior after effect, ② morphological trait easy for grafting, ③ no unfavourable effect on produced fruits, and ④ high resistance to objective soil born diseases.

(1) Stock for cucumber

Summer type (the northern China type) cucumber, *Cucumis sativa*, was widely accepted by consumers in Japan owing to its excellent flesh quality and thin skin. Its constant supply through a year was strongly required by vegetable markets. But, the summer type cucumber is adapted to warm season cultivation system from early summer to autumn, while its root growth becomes inferior during low temperature season resulting in poor yield.

A member of the Nat'l Hort. Exp. Stn., who visited Europe in 1964, observed that *Cucurbita ficifolia* was used as a stock of cucumber for green house cultivation in Netherlands. Based on this information, *C. ficifolia* was introduced into Japan, and was divided into several strains. Though *C. ficifolia* is not used for human food directly, it was confirmed to be a suitable stock for summer type cucumber by its vigorous root growth under low temperature condition and by high graft-compatibility. *C. ficifolia* is contributing for stable production of summer type cucumber during low temperature season.

(2) Stock for egg plant

Egg plant, *Solanum melongena*, is susceptible to bacterial wilt caused by *Pseudomonas solanacearum* and to verticillium wilt caused by *Verticillium dahliae*. Resistant stocks against these two diseases, therefore, was strongly required by farmers. Mass screening for resistance to the two diseases was conducted at the Nat'l Veget. Res. Stn., and *Solanum torbum* was selected to be resistant against the two diseases. *S. torbum* which was introduced from Puerto Rico University in 1976 has a complete resistance to fusarium wilt and a high level of resistance to bacterial wilt, verticillium wilt and root-node nematode (*Meloidogyne* spp.). As the fruit of grafted egg plants did not contain any toxic alkaloid from *S. torbum* stock, *S. torbum* was named "Torbum vigor' in 1983 as a suitable stock for egg plant with high graft-compatibility.

(3) Stock for watermelon

Watermelon, *Citrulls lantus*, is susceptible to fusarium wilt caused by *Fusarium oxysporum* f. sp. *niveum*. Bottle gourd, *Lagenaria siceraria*, therefore, has been used as a stock to protect watermelon from fusarium wilt in major watermelon producing areas in Japan. A newly differentiated fungus race virulent to the bottle gourd appeared in these areas, and resulted in serious damage.

Pumpkin, *Cucurbita moschata*, and white gourd, *Benincase hispida*, are resistant to fusarium wilt caused by existing and newly differentiated races, but they have not been accepted by farmers as a stock for grafting watermelon because of its poor growth habit and inferior fruit quality of grafted watermelon.

Mass screening for resistance to the newly differentiated race of fusarium wilt was conducted at Kurume Branch of the Nat'l Veget. Res. Stn. with bottle gourd collections, and one accession which was introduced from Taiwan in 1981 segregated resistant individuals. A fixed resistant line selected from this accession was named 'Renshi' in 1983 as a stock for watermelon. 'Renshi' is contributing to stable watermelon production in the problem areas.

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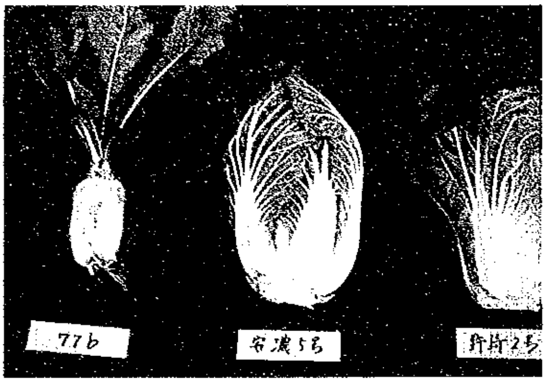

Photo 13. Source of clubrot resistance (left), a developed resistant line (center) and a control cultivar (right). (H. YOSHIKAWA)

Photo 14. A developed line resistant to J3 race of *Fusarium oxysporum* (left) with healthy root and a susceptible control (right). (K. YAMAKAWA)

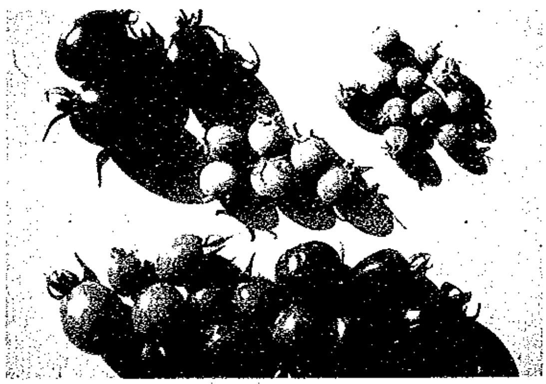

Photo 15. Incorporation of resistance to TMV and J3 race of *Fusarium oxysporum* from *Lycopersicon peruvianum* (PI 126944) (upper right) with F1 hybrids (center) and backcrossed progeny (below). (K. YAMAKAWA)

Ornamental Plants

by

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CONTENTS

1. Chrysanthemum

Chrysanthemum is one of the representative flowers which have much related to Japanese culture since old times. It is also one the most popular flowers in terms of production and consumption.

It is assumed that the prototype of the contemporary chrysanthemums was originated from the hybrids between a tetraploid species of *Chrysanthemum indicum* var. *procumbense*, which is native to North China, and a diploid species, *C.zawadskii* var. *latilobum*, which is native to Central China. Most of the wild chrysanthemum species are native to the Far East Asia. About 19 species among them are native to Japan. It was estimated that the original types for contemporary chrysanthemums were introduced into Japan from China in the Nara Era (the 8th century). Since then, various types of chrysanthemums had been produced in Japan, for example, there are classic chrysanthemums, Saga-type, Higo-type and Ise-type, and those of contemporary types favored by amateurs like large-flowered one, and small-flowered type for cascade use and so on. Japan is the treasure-house of chrysanthemum germplasms not only in the wild species but also in cultivated varieties. There exists a polyploidy series in genus *Chrysanthemum*, where basic chromosome number is nine ranging from diploids, tetraploids, hexaploids, octaploids and to decaploids in wild chrysanthemum species (Fig.1). Contrastingly, most of cultivated varieties were assumed to be hexaploid composing an aneuploidy series with a center of 54 chromosomes (2n number).

An instance of the use of wild species in chrysanthemum breeding can be seen in the interspecific hybridization which has been conducted at the National Research Institute of Vegetables and Ornamental Plants and Tea (NIVOT), MAFF. From the result of crossing between *C.weyrichii* which has spring flowering habit and dwarf plant type in one hand, and spray type cultivars (*C. morifolium*) which has a clear flower color in other hand, the clone 'Chrysanthemum Anou 1' was selected. It has lavender flower color and can flower twice a year. As the result from the crossing between *C. pacificum* and spray type cultivars, Chrysanthemum Norin 5, 'Moonlight', was raised in 1986. It has a vigorous growth habit and a large number of flowers in clusters. These characteristics was derived from *C.pacificum*.

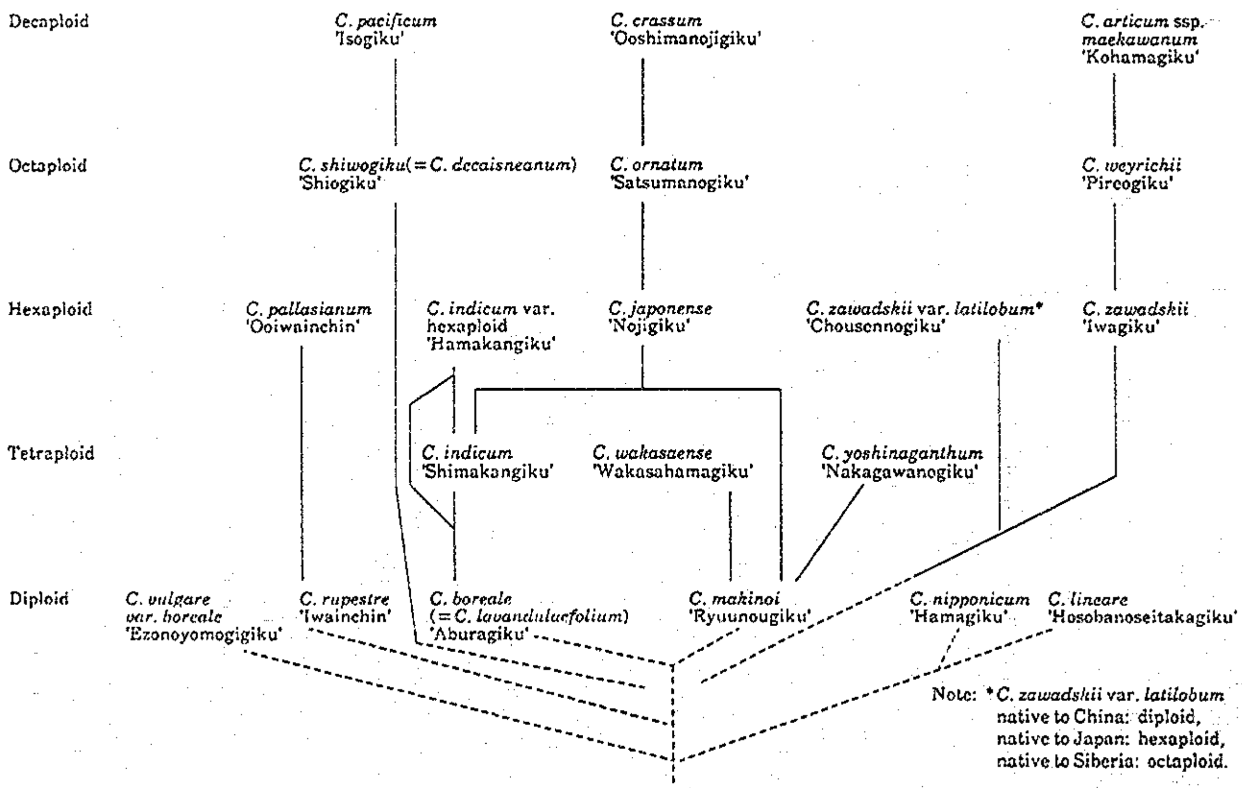

Fig. 1 A genealogical tree in chrysanthemum wild species native to Japan on the basis of their characteristics (form, ecological distribution, geographical distribution, cross compatibility, karyotype and genome constitution). (TANAKA 1982)

Although the crossing was limited among cultivated chrysanthemums, the breeding of summer-to-autumn flowering chrysanthemums can be highly appreciated as the remarkable achievement in chrysanthemum breeding. While autumn flowering chrysanthemums were popular in the Western countries, there have been summer-flowering mutants which lack the requirement for short day in Japan. As the results of selection of various flowering habit, those cultivars flowering in June, July, August, September, October, November, or December have been produced. Especially, Mr. Naoshiro KOIDO, a private breeder in Nagano Prefecture, has been raising the contemporary July-to-September flowering cultivars by repeated crossing and selection for several decades. As there are promising materials for the breeding of heat tolerance among them, they are going to be brought into use for practical breeding program.

Note: New scientific name, *Dendranthema*, has been come into use for genus *Chrysanthemum*. However, the old genus name is used as a matter of convenience in this articles.

2. Carnation

Carnation is well received by Japanese people as a flower of Mother's Day. It is classified to genus *Dianthus*. There are more than 300 wild species in the genus *Dianthus*. They are distributed over Europe, along the Mediterranean Sea, Asia, mountains of the Torrid Zone and South Africa. Perennial wild species, *D. superbus*, *D. japonicum* and etc. are native to Japan.

It is considered that the origin of contemporary carnations was probably hybrids, although the scientific name, *Dianthus caryophyllus*, given to the wild species native to Europe has been used. The carnation breeding had been initiated in Europe. And later, the perpetual carnation, a prototype of the contemporary carnation, was born in the USA in the 20th century. Although European carnations had one season flowering habit, American carnations had perpetual flowering habit. The characteristics of perpetual flowering habit is assumed to be derived from *D. chinensis* native to China.

For a long time until quite recent, large-flowered cultivars, 'Sim' group, which were the sports family and their hybrids from 'William Sim' were raised in the USA, have been the leading varieties for a long time. For recent years, various type of new carnations, 'Mediterranean Carnations', 'Micro Carnations', 'Mignon Carnations', 'Multiflora Carnations', 'Dianthini Carnations', 'Midi Carnations' and etc. have been released.

Wild species besides *D. caryophyllus* were used for the breeding of small-flowered carnations. As an instance of those species, *Dianthus knappii*, which has a yellow flower colour, can be given. A Japanese small-flowered carnation, cv. 'Angel' was raised by Mr.Yasutane KIMURA in 1964. This variety is derived from a double cross, 'Mikado-Nadeshiko' (the hybrid between carnation and *D. chinensis*), 'Improved *D. chinensis* var. *laciniatus*', 'Margalet Carnation' and 'Enfant de Nice'.

In order to prevent from calyx splitting and give the resistance to Fusarium wilt (*Fusarium oxysporum* f. sp. *dianthi*), today in the commercial breeding programs, useful characteristics have been introduced into carnations mainly in 'Mediterranean' group. In Japan, the breeding for resistance to Bacterial wilt (*Pseudomonas caryophylli*) and for the heat tolerance have just been started at NIVOT. For the breeding of heat tolerance, *D. japonicum* is considered to be useful as a breeding material, as it can flower even under hot summer condition in Japan.

3. Lily

There are approximately 100 species in genus *Lilium*, which are mainly distributed in the North Temperate Zone. About 15 species are native to Japan. As most of them are important species in lily breeding, Japan is a treasure-house in lily germplasm. Wild lilies are valuable as ornamental plants in themselves. These are good instances of the direct use of germplasm. *Lilium longiflorum* native to southern Kyushu and Taiwan and *L. speciosum* native to Japan, China and Taiwan are the representative instances. On the other hand, the interspecific hybridization in *Lilium* have been conducted for a long time. The interspecific cross breeding were conducted in Japan as follows.

Lilium longiflorum is the most popular lily in Japan. This has been exported to the Western countries after the World War II. This has been called as Easter lily and has got a popular position in the place of *L. canditum*. Mr.Susumu NISHIMURA in Nagano Pref. released *L.×formolongi* in 1939 by the crossing between *L. longiflorum* and *L. formosa*. *L.×formolongi* could flower within a year after seeding, and had wide leaves and pure white flower color, because *L. formosa* native to Taiwan was closely related to *L.longiflorum* and had the habit of flowering within 10 months from seeding. As the result of the progress by *L.* ×*formolongi*, this has widely been used as a lily in place of *L.longiflorum* in summer in Japan.

Hybrids using *L.speciosum*, *L.auratum* and etc. were called as Oriental Hybrids. They have a common drawback, being not resistant to lily mosaic disease and out facing or pendulous bloom. To improve them, Lily Norin 1, 'Pacific Hybrids', were raised by a cross between *L. auratum* var. *platyphyllum* and *L. speciosum* at the Horticultural Research Station (the former of NIVOT) as a seed-propagated lily. They had very large flowers and no-marking in flower petals. Recently, Lily Norin 6, 'Hinohana', was released by using *L.henryi*, which is highly resistant to mosaic disease, through a cross breeding at Vegetable and Ornamental Crops Research Station (the former of NIVOT). This cultivar is resistant to mosaic disease and *Fusarium oxysporum* f. *lilii*.

Recently, cultivars with an upright flower shape have been raised in the group of Oriental Hybrids abroad, and had been rated highly. This characteristics is considered to be derived from *L. nobillissimum*.

L.×*elegans* has been raised by the crossing between *L.maculatum* native to Hokkaido and *L.dauricum* native to Central Japan in the beginning of Edo Era. Later, through the crossing among *L.*×*elegans*, *L.lancifolium*, *L.leichitlii* and etc., Asiatic Hybrids were raised in foreign countries. Those cultivars had a yellow or red flower color formerly, but recently, white and pink flowered varieties have been released much more in Japan and abroad. It is considered that this characteristics was derived from *L.cernuum*, which has a white flower color.

Wide cross between distantly related species has been conducted in genus *Lilium*. Mr.Hisahiro TAKIZAWA, a private breeder in Niigata Pref., succeeded in getting the hybrid cultivar, cv. 'Yukinohikari', between *L.auratum* and *L.*×*formolongi* using a mixed pollination technique. A successful breeding technique in *Lilium* wide cross is the rescue of hybrid embryo through embryo culture and the intra-stylar pollination. An intact embryo develops no longer after hybridized between distantly related species, so that the hybrid must be rescued before dying in an artificial medium. This technique has been used for more than 40 years. The cross-incompatibilities occurred in an unbalance of the length between style and pollen tube. In the intra-stylar pollination technique, style is cut short prior to the artificial pollination. A lot of hybrids were obtained by Dr.Yoshito ASANO, Hokkaido University, using the intra-stylar pollination and embryo culture. A pink colored and trumpet flower shaped cultivar, 'Rote Horn', is raised by a crossing between *L.longiflorum* and *L.×elegans* using these methods.

4. Tulip

Tulip, a leading component for spring flower beds, is a representative flower in spring. About 150 species are distributed in the Central Asia and along the Mediterranean Sea in genus *Tulipa*. Tulips were introduced into Europe in the 16th century and the breeding was begun later. Although the scientific name, *Tulipa gesneriana*, is given to the present cultivars, this species in itself is considered to be a hybrid. The origin of cultivated tulips was not exactly clarified.

In the tulip breeding, the raising of Darwin Hybrid Tulips in Holland after the World War II is remarkable as a successful instance of the use of germplasm. Darwin Hybrid Tulips were born by the crossing between *T.fosteriana* and Darwin Tulips. They had a larger plant and flower, and flowered earlier than any other tulips which had existed till then. Also a lot of sports appeared from them later, so that Darwin Hybrid Tulips participated in leading varieties giving a leap in the breeding. Darwin Hybrid Tulips, which were bred in the initial period, were all triploids. It was a mystery that triploids have never been obtained again even by similar crossings since then.

In Japan, the breeding of tulips has mainly been conducted at Toyama Vegetables and Ornamental Crops Research Station. The raising of other flower color in Darwin Hybrid Tulips besides the original red one was remarkable. As a parent, *T. fosteriana* cv. 'Purrishima' (white) instead of cv. 'Red Emperor' (red) was adopted to the crossing. As the results, new Darwin Hybrid Tulip cultivars , cv.'Usugeshou' (pink), 'Shirayukihime' (white) and 'Kikomachi' (yellow), have been raised up.

Despite the large number of wild species, only a few species have been used for the breeding of the contemporary tulips. After a survey of the cross compatibility among species in the genus *Tulipa* by Dr.Kaoru HAGIYA, *T. tubergiana*, was found to be promising, which is characterized by large plant and flower.

In tulip breeding, it is a serious problem that it takes a very long time from crossing to raise a practical cultivar. Five or six years are necessary from seed to first flowering. Furthermore, the number of bulbs is multiplied only 2.5 times a year, so that it takes nearly 20 years to release a practical cultivar. The exploitation of technique to reduce juvenile phase and to rapidly multiply bulbs by tissue culture are eagerly expected.

5. Rose

Genus *Rosa* contains approximately 100 species. They are distributed all over the Northern Hemisphere. About 30 species are native to Japan. Although roses has been cultivated since several thousand years ago, its artificial breeding began not long ago. The Empress JOSEPHINE, who collected large numbers of roses in her garden at Malmaison in the 19th century, much contributed to the progress of the breeding in contemporary roses. The breeding of roses have been conducted mainly in Europe. The breeding process of the contemporary roses was complicated and was not exactly clarified.

The pedigree of contemporary roses was shown in Fig. 2. There are three monumental progress in the breeding process of contemporary rose. The first was the raising of the Hybrid Tea roses which had large flower and ever-flowering habit. They were produced by a cross between the Tea roses, which had ever-flowering habit, and the Hybrid Perpetual roses, which had large flowers. The second was the raising of the Floribunda roses. They were derived from a cross between the Hybrid Polyantha roses and the Hybrid Tea roses. They had medium-size flowers and a lot of flowers in clusters. They were also endowed with hardiness characteristics from *R.multiflora* native to Japan. The third was the raising of the Grandiflora roses by a cross between the Hybrid Tea roses and the Floribunda roses.

Judging from the scientific name, *Rosa*, the color of the ancient roses was considered to be dark red, expressed by a kind of anthocyanins, cyanidin. The color range of early introductions lacked yellow color. Yellow rose has been introduced by a cross with *R. foetida* native to Asia Minor, which was the only species to express yellow pigment, carotenoid. Later, the bright red color has been introduced into the Hybrid Polyantha roses by an expression of other kind of anthocyanin, pelargonidin, which was derived from *R. multiflora*. As the results, the wide range of flower color was introduced to the Floribunda roses. Even blue flower color is expected in future. But so far, no breeding material with blue pigment, delphinidin, has been found.

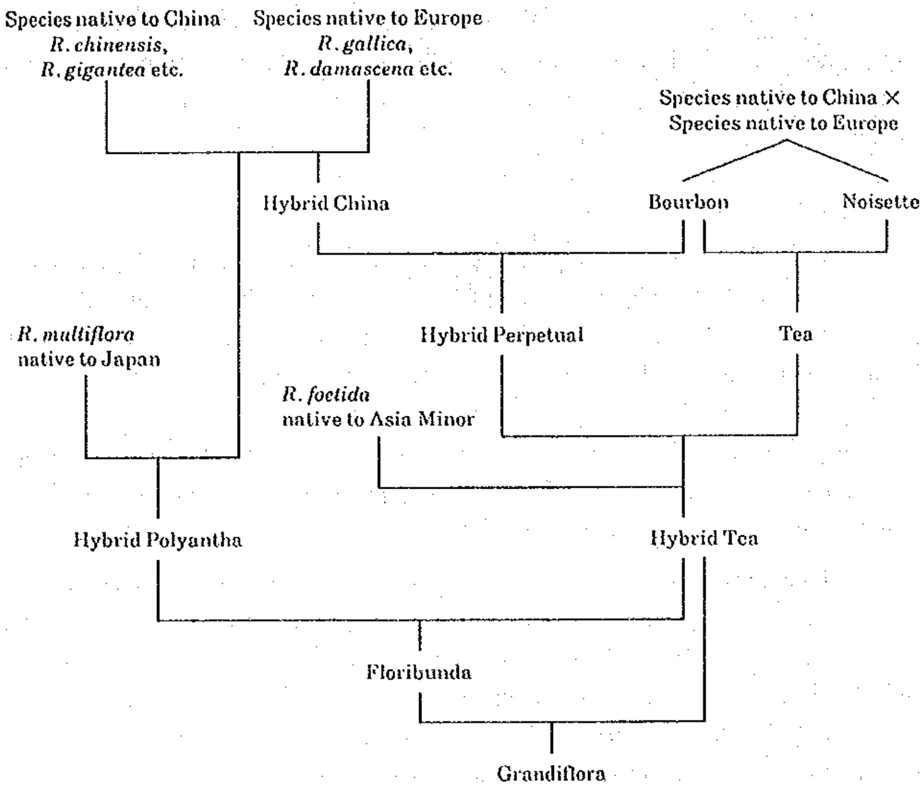

Fig. 2 The pedigree of the contemporary roses. (YASUDA 1980)

The cultivation of roses are normally conducted by grafting. *R.multiflora* is used as root stock in Japan, *R.* 'Manetti' in the USA, *R. indica* in France and *R. canina* in Germany. The characteristics of wild species as a root stock are important in the view point of yielding ability, disease resistance and the soil adaptability. Although *R. multiflora* is vigorous in growth and resistant to black spot (*Diplocarpon rosae*), it is not resistant to crown gall (*Agrobacterium tumefaciens*). At the Kanagawa Horticultural Research Station, root stock strains resistant to crown gall have been selected from the strains of *R. multiflora* collected from many places in Japan. The breeding of root stock strains is also important in roses.

6. Orchid

Orchid family is a general name of the plants which belong to Orchidaceae, Monocotyledoneae. There are a lot of popular flower kinds in this group as follows: *Cymbidium*, *Cattleya*, *Dendrobium*, *Phalaenopsis*, *Paphiopedilum*, *Miltonia* and etc.

There has been a custom that a newly crossed combination in orchid cultivars is registered to the Royal Horticultural Society in the UK. This custom has been exactly observed without exception all over the world. So the parents, the characteristics, the first flowering date and etc. for all hybrids have completely been recorded since 1895. Though the origin of most of important flowers has scarcely been clarified, it is remarkable that the information of germplasm utilization has been there in orchid breeding almost perfectly.

As an instance of breeding process in orchid cultivars, a pedigree of cattleya cultivar, *Lc.* cv. 'Judy Small', with splash in flower color was shown in Fig. 3. We can easily find out that the characteristics of splash color was derived from *Cattleya intermedia*(var.*aquinii*).

A large number of orchid cultivars have been raised not only by interspecific crossing, but also by intergeneric crossing. For example, the cultivars, normally classified to cattleya group, were derived from the crossing between genus *Cattleya*, genus *Sophronitis*, genus *Laelia* and genus *Brassavola*. Such new genus names were used for hybrids, as *Lc(Laeliocattleya)* for the intergeneric hybrids between *Laelia* and *Cattleya*, *Slc(Sophrolaeliocattleya)* for the intergeneric hybrids between *Sophronitis*, *Laelia* and *Cattleya*.

A symbiosis with fungi is necessary for germination of orchid seeds in natural condition. Most of the hybrids in orchid have been obtained by artificial germination on sterilized agar media containing sucrose since Knudson's study.

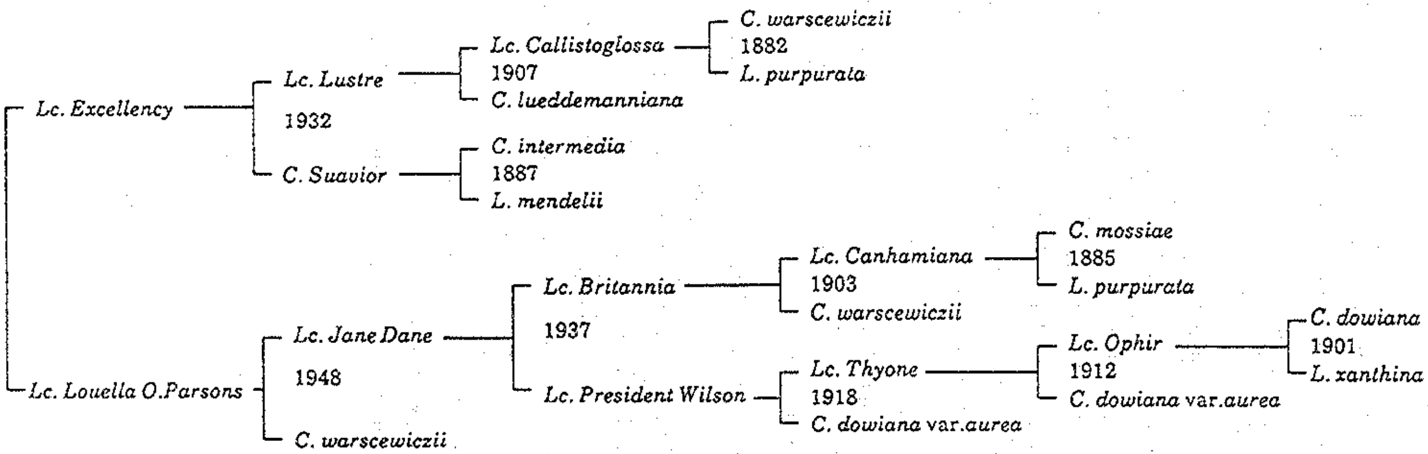

Fig. 3 The pedigree of cattleya with splash in flower color, *Lc. Judy Small* registered in 1960.
(800 Cattleyas of the World, ed. by the supervision of the Japan Orchid Growers Association, 1982)

7. Rhododendron and azalea

Both rhododendrons and azaleas are classified to genus *Rhododendron*. This genus is very large and consists of approximately 800 species. Most of the species are distributed over the Northern Hemisphere, mainly from the Himalayas to central and western China. Several species are distributed over the Torrid Zone.

Cultivars belong to genus *Rhododendron* are roughly classified to the following three groups: Non-scaly Group, Scaly Group and Javanicum Group (Vireya Series). Cultivars of rhododendron and azalea cultivars are contained to Non-scaly Group.

Breeding of Rhododendron cultivars had been begun by making use of wild species native to the Himalayas, central and western China and the North America in Europe, and later has been progressed in the USA. *Rhododendron metternichii*, *R.metternichii* var. *pentamerum* (= *R.degronianum*), *R.makinoi* etc. in this group are distributed to Japan.

Because the original wild species of contemporary rhododendron cultivars are native to highlands, where the summer climate is cool, most of the cultivars are not fitted to summer in Japan. As *R. mitternichii* var. *yakushimanum*(=*R. yakushimanum*) in itself is much valuable as ornamental plants, it was already introduced into Europe and has been used as a breeding material. As this species is comparatively distributed to warmer areas among wild rhododendrons, it is evaluated to be useful in the breeding for heat tolerance.

Further, azaleas are classified to an ever-green type or a deciduous type. Ever-green azaleas are native to Asia, mainly Japan. Satsuki azaleas, Hirado azaleas, Kurume azaleas and Miyamakirishima azaleas were raised by improving wild species in the Edo Era in Japan. They are widely valued by Japanese people as potted plants and garden shrubs. The origin of cultivars in ever-green azaleas were almost clarified. For example, two wild species, namely *R. sataense* and *R. obtusum*, both of which are native to the southern Kyushu, are considered to have closely related to the raising of Kurume azaleas.

Belgian azaleas were developed in Europe by using *R. simsii* native to China as a breeding material. They are much familiar in the form of potted plants all over the world. As they had been raised for greenhouse production, they were not hardy to cold but scarcely have dormancy. So it is possible to conduct forcing culture by heating in Belgian azaleas. The inter-specific hybridization between Belgian azaleas and Japanese wild species have been conducted in order to incorporate hardiness into Belgian azaleas at the Kurume Branch of NIVOT. The hardy Belgian azalea cultivar, Tsutsuji Norin 1 'Benifusha' was selected from interspecific hybrid seedlings of *R. scabrum* cv. 'Shonoshin kerama' and *R. simsii* cv. 'Robin' there. The interspecific hybridization between distantly related species have also been attempted in genus *Rhododendron*. However, there remained a big problem that most of germinated seedlings lacked chlorophyll, even though the crossed seeds are obtained. An exploitation of technique to overcome this kind of barrier is necessary.

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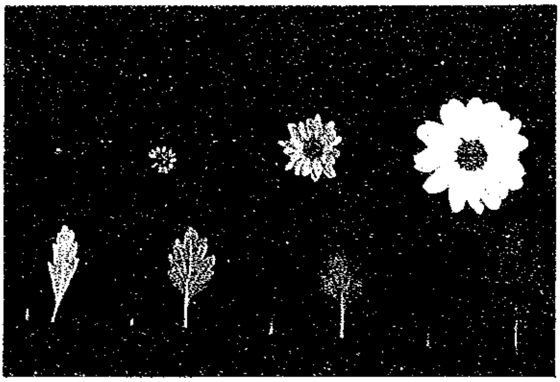

Photo 16. Interspecific hybrids between *Chrysanthemum pacificum* and *C. morifolium* (for spray type).
from the left; *C.pacificum*, 22-B (*C. pacificum* × *C. morifolium*), Chrysanthemum Norin 5 'Moonlight' (22-B × *C. morifolium*), and *C. morifolium* cv. 'Snow Queen'. (M. SHIBATA)

Photo 17. Lily Norin 6, 'Hinohana'. (Y. HIRATA)

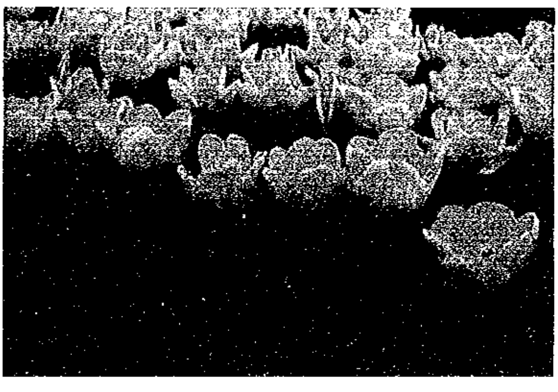

Photo 18. Tulip Norin 13, 'Kikomachi'. (M. SHIBATA)

Sugar, Oil and Other Industrial Crops

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1. Sugarcane

Cultivated sugarcane are classified into two groups. One is a noble cane (*Saccharum officinarum*) group possessing thick culm, high sugar content and juicy characteristics. The noble cane group is considered to be originated from a New Guinean indigenous species *S. robustum* which possesses long, thick and sugarless culms. The other is a thin culm cane group belonging to *S. barberi* in India and *S. sinense* in China. The thin culm cane group possesses thin and numerous culm, low sugar content and wide adaptability. Japanese land races of sugarcane were considered to be derived from *S. sinense* of the thin culm cane group. Cultivars of the noble cane group were first introduced into Japan during Meiji era.

Almost all the cultivars planted today are considered to be originated from very complicated interspecific hybrids which were mainly derived from germplasms of the noble cane group with addition of disease resistances from a cultivar 'Chunnee' of the Indian thin culm cane group and from an Indonesian wild relative species *S. spontaneum*. The polyploidy owing to fertilization of unreduced ovules was also considered to have played a major role in the establishment of modern cultivars by thickening of culm. It should be noted that modern cultivars which are called as the "Java thick culm cane group" were mostly developed from crosses including 'POJ 2878' and its sib-cultivar 'POJ 2725'. 'POJ 2878' and 'POJ 2725' were praised by the name of "Wonder Cane" for their superior combining ability which contributed to the establishment of modern cultivars.

Practical cultivation of the sugarcane in Japan was started with the introduction of 'POJ 2725'. It was stabilized after introducing 'NCo 310' which has wide adaptability in high latitude areas.

As Japan is in the northern limit of sugarcane cultivation, development of stable cultivars for the severe climate in planting area is of primary importance. Consequently wild species and wild relatives are expected to be valuable genetic resources. In Japan, even at the southern most island, Okinawa, only a part of breeding materials produce crossed seeds, while most part of breeding materials failed to set crossed seeds not only outdoors but also in greenhouse. The Nat'l Kyushu Agr. Exp. Stn. which is responsible for sugarcane breeding in Japan has introduced hybrid seeds from India, Taiwan and South Africa by the order of hybridization program.

2. Sugar beet

Sugar beet (*Beta vulgaris*) is in a group of high sugar content beet which was selected from forage beets in Europe, and was introduced into Japan during Meiji era. Accordingly, all the cultivars in Japan are introduced germplasms. The Nat'l Hokkaido Agr. Exp. Stn., which is responsible for sugar beet breeding in the national network, developed 'Hon iku 192' from introduced European germplasms, and tried to develop triploid cultivars. Unfortunately, basic germplasms of breeding materials in Japan were susceptible to Cercospora leaf spot caused by *Cercospora beticola*, consequently all the cultivars developed in Hokkaido were susceptible. After the World War II, a USA cultivar 'GW 359' developed by Great Western Co. was released by the name of 'Dounyuu 2' (Introduced cultivar 2) after a mass selection conducted at the Nat'l Hokkaido Agr. Exp. Stn.. It became soon popular in Hokkaido owing to its outstanding tolerance to the disease and high yielding ability.

A cone of sugar beet contains several seeds in it as a nature of Chenopodiaceae, and two to three seedlings germinate from one cone. This character of multigerm seed forces farmers painful work for thinning after germination. Sugar beet breeders, therefore, looked for a germplasm of monogerm seed to relieve growers of the painful work. Fortunately, a gene for monogerm seed was discovered in USA in 1950, and a strain 'Tmm-1' possessing *m* gene was introduced into Japan. The *m* gene has been utilized not only in Japan but also all over the world for developing monogerm cultivars. Thus, the most of modern cultivars developed in the world are monogerm, of which the word of mono- or solo- attached to the head of each varietal name means monogerm cultivar.

Sugar beet exhibits remarkable heterosis in its yield. But, F_1 seed production of sugar beet is very much difficult without utilization of genetic male sterile system because of its cross fertilization nature. Cytoplasmic male sterility of sugar beet was discovered in USA in 1945, and confirmed to be caused by an interaction between male sterile cytoplasm (S) and two sets of restorer gene (X,Y). Male sterile individuals, therefore, possess the genotype of (S)xx,yy, and a set of male sterile lines and its corresponding maintainer lines with (N)xx,yy are utilized for producing female parents in the F_1 breeding scheme. Such a maintainer line is called O type line by sugar beet breeders .