データベースから見た世界の突然変異育種

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MUTATION BREEDING IN THE WORLD AS SEEN IN THE DATABASES

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Introduction

Information of world situation in mutation breeding has been collected well in the Joint FAO/IAEA Division in IAEA. The Division is composed of five Sections which relate to agricultural application of atomic energy in the field of agriculture, from soil science to product preservation, all related to agricultural activities in the world related to nuclear technologies. Among them, Plant Breeding and Genetics Section relates to improvement of crop varieties using mutation techniques. The Section has published their collected information on the improved varieties by mutation techniques, and such mutant varieties, registered or released officially in various countries in the world, now amounted over 2000 varieties. The information have been constructed to a simple database and kept personally. Recently, the database of mutant varieties has been officially opened from the IAEA in a form available on internet. The trends observed in such databases suggested some interesting facts.

Presentation here also includes some information on the recent situation of GM crops in USA. The method to analyze the genetic resources database of USA was kindly suggested by Dr. Karin Nichterlein, IAEA, and Prof. Steve Ullrich, Wash. State Univ. According to their suggestions, the US Genetic Resources Database was searched on internet system and two important trends were seen. 1) Plant breeders use good genetic resources without recognizing the origin, thus they do not care reporting to IAEA as indirect use of mutant line in their new variety; 2) The significant recent trend in crop, having very rapid growth in planting area, may be GM (Genetically Modified) crops, GM maize, GM soybean, GM cotton, GM tomato etc. in which crop species mutant varieties are seldom, or not at all registered in the US genetic resources database. In case of maize, due to its strange reaction to ionizing radiation, i.e. almost all radiation induced mutants were deletion mutant and often accompanied with unfavorable survival and other defects (Stadler and Roman 1948, Mottinger 1970 and Amano 1972 and 1985), less mutant varieties reported may be understandable, however, the plant can respond to chemical mutagen very well like other crop plants (Amano 1968). In this paper, some perspectives found by examining the databases are reported.

Activities in IAEA

The International Atomic Energy Agency (IAEA) is one of the organization in the United Nations (UN). For agricultural sector, a joint division between Food and Agriculture Organization of UN and IAEA has been organized, and Plant Breeding and Genetics Section promotes crop improvement through mutation techniques. They had collected data on achievements of the methodology as mutant varieties, officially registered and/or released. The collected data on such mutant varieties have been published in their newsletters, "Mutation Breeding Newsletter" and "Mutation Breeding Review".

The database based on the IAEA publication

The published data of the mutant varieties were organized in a personal database in BASIC language for PC, and updated when new issues came up. The primitive BASIC program can be still operated on Wang BASIC on Windows 98 (also on Windows-Me), if MS-DOS is available. The oldest mutant variety found in this database was cited from the Mutation Breeding Review No.3, as follows :

Nicotiana tabacum L. Chlorina F1 Indonesia 1934 X-rays 1930
(Vorstenland) pale color high leaf quality IAEA 1974

The record is shown in order of academic name, variety name, country, released year, mutagen used, treated year, original variety used in parenthesis, mutant character and reference. This might be an exceptional example, appeared only several years after the reports by H. J. Muller (1927) and L. J. Stadler (1928). Number of mutant varieties increased significantly after the World War II, due to development of gamma irradiation sources and facilities produced by nuclear reactor and related technology.

In the collection of mutant varieties, two types of definitions are often used, 1) direct use and 2) indirect use. The direct use means registration and/or release of mutant line directly as variety, both in seed propagated (e.g. rice, barley *etc.*) and vegetatively propagated (fruit tree, chrysanthemum *etc.*) crops. Indirect use is for cross bred varieties using mutant line(s) as parent(s). It may be understandable that if there were no such mutant induced by the mutagenic treatment, such favorable variety would not be developed. The definition is also respected in Japan. The achievements in Japan were reported by Dr. Isao YAMAGUCHI, somewhere in this Symposium Proceedings.

Total number reported in the IAEA publications (Mutation Breeding Newsletter *etc.*) amounted to about 1900 varieties, as of MBNL No.44, April 1999. Recently, the entire database was opened to be viewed on an IAEA internet database. The total number was over 2200 varieties as of January 2001. Each data records are shown as reported and may not show genetic details. However, they give us some interesting scope of mutation work in the breeding of crop in each country.

Some interesting features seen in the data

From the database based on the published data in MBNL and MBR by IAEA, key-word searching revealed a result shown in the Table 1.

Table 1. Plant cultivars derived from mutation induction or the use of induced mutants in cross breeding. Data from Mutation Breeding Review (No.3, 1986,3) and Mutation Breeding Newsletter (up to No. 44, 1999,4) were analysed by keyword searching.

Country	No. of var.	Mutant used in cross	Crops: Cereals					Crops: Legume			Crops: Ornamental			Crops: Fruit		Crops: Other		Mutagen*					Note**
			Oryza	Hord.	Triti.	Zea	Other	Glyc.	Phas.	Other	Chrys.	Flower	Leaf	Arbo.	Herb.	Fibre	Other	X	G	N.	Other rad.	Chem.	
China	314	73	117	1	81	23	4	23	0	26	0	7	0	3	2	8	22	9	218	17	2	3	las 14
India	253	42	35	14	4	0	5	0	3	35	46	57	0	1	9	13	31	28	145	7	5	26	chr 8
Russia(USSR)	209	72	6	28	36	12	12	9	4	30	17	7	1	9	4	4	30	1	56	0	5	86	las 1
Netherland	176	1	0	1	0	0	0	0	0	0	80	93	0	0	0	0	2	153	17	5	1	3	
Germany	140	48	0	46	2	0	2	1	2	1	34	45	0	1	0	0	6	57	29	0	1	5	
Japan	120	43	46	8	2	0	1	6	0	1	14	9	8	4	4	3	14	2	74	0	2	4	chr 16
USA	105	51	23	11	3	0	11	0	6	1	1	20	8	2	0	0	19	10	29	17	2	6	
France	42	14	5	15	1	0	0	0	0	0	0	14	0	7	0	0	0	0	24	0	0	4	chr 1
Italy	35	9	1	0	15	0	0	0	2	6	0	0	0	5	4	0	2	7	8	5	0	7	
Czech(CSSR)	34	25	0	27	0	3	0	1	1	1	0	1	0	0	0	0	0	2	3	0	0	2	chr 3
Brazil	34	3	27	0	2	0	0	0	2	0	3	0	0	0	0	0	0	0	31	0	0	0	chr 26
UK	33	31	0	32	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	
Bulgaria	30	6	0	4	6	8	0	3	0	1	1	1	0	1	3	0	3	2	14	0	0	1	
Poland	30	17	0	1	0	0	0	0	1	21	6	1	0	0	0	0	1	4	9	0	0	0	
Cote d'Ivoire	26	17	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	chr 9
Guyana	26	0	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	0	0	0	chr 26
Sweden	26	20	0	20	0	0	0	0	0	1	0	0	0	0	0	0	5	6	0	0	0	0	
Pakistan	24	0	4	0	4	0	0	0	1	12	0	0	0	0	0	2	0	0	18	1	0	2	
Vietnam	24	6	14	0	0	2	0	4	0	1	0	0	0	2	0	0	1	0	9	0	0	12	
Belgium	22	1	0	1	0	0	0	0	0	1	7	8	3	0	0	0	2	16	10	0	0	2	
Canada	22	12	0	2	0	0	0	0	1	0	0	4	0	8	0	2	4	7	2	1	1	2	
Denmark	22	20	0	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	
Iraq	22	2	2	7	6	0	0	0	0	2	0	0	0	0	0	0	5	0	17	3	0	0	
Austria	20	17	0	12	6	0	0	0	0	1	0	0	0	1	0	0	0	1	2	0	0	0	
Bangladesh	16	3	3	0	0	0	0	0	0	3	0	0	0	0	1	3	6	2	6	0	0	2	
Finland	11	6	0	4	1	0	6	0	0	0	0	0	0	0	0	0	0	2	3	0	0	0	
Indonesia	11	1	6	0	0	0	0	3	0	1	0	0	0	0	0	0	1	1	9	0	0	0	
Korea	11	2	2	1	0	0	0	2	0	0	0	0	0	0	0	0	6	4	1	2	0	3	
Thailand	9	1	4	0	0	0	0	1	0	0	2	1	0	1	0	0	0	0	7	1	0	0	
Austral ia	7	3	0	0	0	0	2	1	0	4	0	0	0	0	0	0	0	0	0	0	0	4	
Argentin	6	0	0	0	1	0	0	0	0	2	0	0	0	3	0	0	0	3	2	0	1	0	
Estonia	6	5	0	5	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	
Hungary	6	1	3	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	2	2	0	1	chr 3
Cameroon	4	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	
Myanmar	4	1	2	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	3	0	0	0	
Burkina Faso	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Costa Rica	3	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	3	0	0	0	
Egypt	3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	3	0	0	0	
Mongolia	3	2	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	
Nigeria	3	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	
Philippines	3	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0	
Sri Lanka	3	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	3	0	0	0	
Chile	2	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	
Greece	2	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	
Kenya	2	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2	0	0	0	
Norway	2	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Senegal	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	chr 2
Ukraine	2	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	
Algeria	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	
Guinea Bissau	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	chr 1
Madagascar	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Portugal	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	
Switzerland	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	
Togo	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
*** Total(cumultv)	1917	564	372	267	177	49	44	55	24	156	212	269	20	48	27	36	164	318	810	64	18	178	chr 95
**** Total(real)	1903	564	341	265	177	49	43	58	24	156	211	265	20	48	27	36	152	318	810	64	18	176	chr 64

* : Mutagen : X : X-rays, G : Gamma-rays, N : Neutrons, Other rad. : In early phase data, some records were without details. Beta rays, electron beam etc. are included here. Chem. : Chemical mutagen.

** : chr : Chronic irradiation, las : Laser irradiation (These are included in G and Other rad. respectively).

*** : cumultv : Cumulative sum of each column (including duplication among countries).

**** : real : Actual biological numbers (without duplication).

The data extends for almost half a century and international situation have changed in some region. But it may still be safe to say that China was the top, followed by India, former USSR and the Netherland. By unification of East and West Germanies, sum of the mutant variety numbers exceeded that of Japan. As shown later, USA seems also overtaking Japan, if all the hidden mutant varieties were reported. In case of former USSR and China, some records are short of genetic information like treatment details. Another feature may be the use of laser as mutagen. It is reported only from China and the former USSR. Scientific rationale should be discussed in other occasion, but here it may be understood to reflect their high activities in this field. If we look a few years back, it may be described that as a general trend China had made good effort mostly in food crops, but recently some ornamental plants have been added, perhaps reflecting their well stabilized status of the country. Compared to it, the Netherland, and also Belgium, paid their effort mostly in ornamental crops until recent year, when an indirect use of mutant in their malting barley appeared, one variety each. The second high activity was shown in India in very wide range of crops, both in direct and indirect uses and also in wide range of mutagens used. Information for each record was also well described in these cases.

Once there was an idea that if a hybrid line were used as the material to be treated by mutagen, the gene-pool treated would be enlarged. It is not clear if they follow this idea or not, but in China and in the former USSR in a few cases they treated hybrid materials. In case of self-incompatible species or with a very special purpose, e.g. translocation induction, it may be reasonable. However, if we consider the recessive form of a gene as an inactivated state, as revealed in the recent gene models, hybridization may only narrow the gene-pool to be treated. Furthermore, hybrid between recessive alleles of a locus may produce normal recombinant, e.g. normal non-waxy (Wx) recombinant from a hybrid of different alleles of waxy mutants, e.g. wx_1^{H21} and wx_1^{90} *etc.* (Briggs, Amano and Smith 1965, Amano 1985). In normal practical cultivation, the frequency of recombination may be negligible, but in the mutagenic experiment, occurrence of such recombination phenomenon at 10^{-4} may be significantly high and the result may be easily confused as a dominant mutation.

Another genetic difficulty may be based on the strange nature of maize plant to the ionizing radiation. As reported by Stadler *et al.* (1948), and supported by Mottinger (1970) and by Amano (1968, 1972), seed of maize plant does respond to ionizing radiation, but only producing deletion type mutation which is very often inferior in their survival of the homo-zygotes, perhaps due to loss of neighboring gene(s). After irradiation, broken chromosome ends can heal, resulting into deletion mutation. Or when pollen grain was irradiated, fertilized seeds often showed a mosaic pattern known as the result of famous breakage-fusion-bridge (B-F-B) cycle, again suggesting some kind of repair system in this plant species. Perhaps repair timing might be different from other crop species. This strange reaction seems only seen after exposure to ionizing radiations. The maize seeds reacted to chemical mutagen, e.g. ethyl methanesulfonate (EMS), very well, like rice seeds. This strange behavior of maize might have suppress the work in the former western countries, but from the former communistic countries, almost 50 mutant varieties have been reported. Among them, those from the former USSR and from Bulgaria were originated from chemical mutagen treatment and seemed to be cases of reasonable and reliable mutations. In another case, in Vietnam, combination of gamma-ray and a chemical mutagen was used suggesting that they might be also a good case of real mutations.

Another feature in the list of the mutant varieties was that some countries, e.g. Cote d'Ivoire, Cameroon, Guyana, Brazil *etc.*, share the same mutant varieties developed by French breeders. Therefore, in the total numbers of mutant varieties at the bottom of Table 1, two totals were shown, one cumulative (including multiple appearances) and one real total (total number of biological or genetic lines).

The review paper on the entire collection of mutant varieties in the Plant Breeding and Genetics Section, IAEA, appeared in No. 12 of Mutation Breeding Review (M. Maluszynski *et al.*, 2000). A total of 2,252 mutant varieties were reviewed in annual accumulation trend, national and area-wise analyses. The crop species reached to 175 entities which was much more than the previous review report in 1995, when the number was 154 species (Maluszynski *et al.* 1995). The list of the entire mutant varieties was shown in a list that extended to 71 pages in this issue, Mutation Breeding Review No.12. Although the total number of mutant varieties listed were more than 2200, at the time of presentation of this report, the IAEA's database had some difficulties in country-wise listings. So, here, only their internet address is shown as information sources.

Survey of mutant varieties

In 1999 and 2000, there was a project to examine economic effect of radiation techniques, in industry, medical and agricultural sectors. In the survey work, I could have opportunities to meet and discuss some matters with IAEA and US researchers. As an independent activity from our Japanese project, the Plant Breeding and Genetics Section of IAEA is also collecting information on the economic impact of mutant varieties in the world. While examining replies to their questionnaire, they noticed that in the USA crop breeders uses many mutant varieties without recognizing that their materials were originated by mutation techniques. This may be understood as that the good varieties will be used regardless of their origin, suggesting good incorporation into classical breeding system. At IAEA the ways to examine the US database on genetic resources was suggested, and almost the same was also shown at the Washington State University. The results of examining the database of genetic resources of the USA were significant in two ways.

1) Many registered mutant varieties (indirect uses) remained as "not-reported to IAEA", in wheat, barley, rice and oat as shown in the Figures 1 through 4. In case of rice, the major breeder Dr. N. Rutger was still active and reported many of the mutant variety of rice developed in the USA as shown in Fig. 3. But in other crops, many varieties remained not reported to IAEA.

2) Recent technologies to introduce external gene through transformation techniques opened a new field of crop breeding, as the output is called genetically modified organism (GMO) or GM crops. Internet information showed a very quick increase in the planted area of GM crops. By the search

Pedigree Search on http://www.ars-grin.gov/cgi-bin
Total 32 cultivars including the original 3 mutant lines which had been reported to IAEA.
Horizontal line:The left most group are original mutants, others being progenies. Column : Sister varieties.
Parenthesis:Second (multiple) appearance, Boxed:Reported to IAEA.

Original mutant line "Payne" 29 varieties

Payne	Century	4 institute lines		
	Bronco			
	Sierra 1, (but not this Sierra)			
	Cimarron	Tascosa	Fox	
			Pronto	
			Chanute	
			Santana	830
			Yukon	
			Palo Duro	
			Blueboy II	Treasure Zak
				Orion
				6 institute lines
			Maverick	
			Texred	
			Exile	
			Cheney	Ike
				2 institute lines
			TAM 106	
			Collin	
			Amigo	Century
				Niobrara
				Rowdy
				Embrapa 16
				Fleming
				Embrapa 52
		Buck Pucara		
		4 institute lines		

Original mutant line "Lewis" 3 varieties

Lewis	Blazer
	Orion
	1 institute line

Original mutant line "Stadler" 6 varieties

Stadler	Stoddard	Ernie	
		Pike	Clemens
			(Ernie)
			Kaskaskia

Fig. 1. Pedigree chart of wheat mutant cultivars in USA.

Pedigree Search on http://www.ars-grin.gov/cgi-bin
Total 106 cultivars including 3 dES induced mutant lines are listed here (Luther's Progeny excluded).
Horizontal line:The left most group are original mutants, others being progenies. Column : Sister varieties.
Parenthesis:Second (multiple) appearance, Boxed:Reported to IAEA, Underlined:Introduced from Europe.

Advance						
Blazer	(Advance)					
Bonneville 70						
Deawn						
Eight-Twelve						
Hesk						
Luther						
Mal						
Nomini						
Pamunkey						
Pennrad						
Pallas						
Diamant	Ametyst	Opal				
		(Heris)				
	Primus					
	Favorit					
	Rapid					
	Spartan					
	Trumpf	Carnival				
		Gerlinde				
		(Cheri)				
		Heriot				
	Nadja					
	Grit					
	Cheri					
	Skiff					
	Atlas	Atlas 46				
		Atlas 54				
		Atlas 57				
		Atlas 68				
		Atsel				
		Arivat	Aristan			
			Arimar			
			Briggs		Kombar	Columbia
					Prato	
			Numar		Kombyne	
			(Bartel)			
			(Westbar)			
			Omer			
			Puebla			
			Weatbred Gustoe			
			Westbred 501			
		Bartel				
		Beecher				
		Bold				
		Bollo				
		Forrest	Onslow			
			Morrell			
		Gem	(Blazer)			
			Hop	Illia		
				Courlis		
				Corsaire		
			Hoppel			
			Clemson 100			
		Glacier	Unitan	Steptoe		Teton
						Colter
						Walker
						(Leduc)
						(AC Rosser)
						UC 937
						UC 960
						UC 933
						Bringham
				(Diamond)		
				(AC Lacombe)		
				Millennium		
			Galt	Klondike	Johnston	(AC Rosser)
						Bacon
					Heartland	(AC Rosser)
					(AC Lacombe)	
					Leduc	Vivar
				Diamond		
				Noble		Trochu
						Vivar
				AC Lacombe		
				AC Harper		
				AC Rosser		
			Hypana			
			Shabet	Ershabet		
				Kaputar		
		Ogra	Sigra			
		Pennco				
		Sussex	Callao			
			GA-Luttrell			
		Venus				
		Volvar	Anson			
			(GA-Luttrell)			
		Westbar	Azhul			
		Wysor				
	Safir					
	Karat					
	Zefir					
	Rubin					
	Heris					

Fig. 2. Pedigree chart of barley mutant cultivars in USA.

Pedigree Search on http://www.ars-grin.gov/cgi-bin
Total 27 cultivars including RD-6 and Kashmir Basmati cited from GRIN.
Horizontal line:The left most group are original mutants, others being progenies. Column : Sister varieties.
Parenthesis:Second (multiple) appearance, Boxed:Reported to IAEA.

A-201		
Calmochi-101	(Calmochi 202)	
	(S-102)	
Calmochi 201		
Calmochi 202		
Calpearl		
Calrose 76	(M7)	
	(M-101)	
	(M-301)	
	(M-302)	M-103
	(S-201)	
	(S-301)	
Delmont		
Lafitte		
M-101	(M-102)	
	(M-202)	
M-102		
M-202		
M-203		
M-204		
M-301		
M-302		
M-401	(M-203)	
M7	(Calmochi-101)	
	(L-205)	
	(M-204)	
	S-101	
	(S-301)	
	Mercury	
S-102		
S-201		
S-301		
S2-Calpearl		
Valencia 87		
Kashmir Basmati		
RD-6		

Fig. 3. Pedigree chart of rice mutant cultivars in USA.

Pedigree Search on http://www.ars-grin.gov/cgi-bin
Total 25 cultivars.

Horizontal line:The left most group are original mutants, others being progenies.

Column : Sister varieties.

Parenthesis:Second (multiple) appearance, Boxed:Reported to IAEA.

Alamo-X	Tam O-312	Amby
		Culogoa
Bates		
Bob		
Florad	(Florida 500)	
	(Florida 501)	
Florida 500	Elan	
	(Bates)	
	Bates 89	
Florida 501	(Bob)	
	(Ozark)	
Centennial		
Hericon		
Ozark		
Bay		
Belle		
Gem	Vigor	Saturn
	Altesse Jaune of Gembloux	
	Diane	Anita
	Junon	
	Jasper	
	Waldern	
Alamo 86		

Fig. 4. Pedigree chart of oat mutant cultivars in USA.

Table 2. Trend of crop improvement method in USA.

Crop palnt	Breeders	Major objective	Method (gene)	Reaction of farmers	Reaction of consumers
Maize	Companies	Anti-corn boarer	GM (BT gene)	Will not accept if market does not accept	Affected by outside, UK, Japan *etc.*
Soybean	Companies	Widen herbicide use	GM (herbicide resistant gene)	Will not accept if market does not accept	Affected by outside, UK, Japan *etc.*
Cotton	Companies	Anti-ball worm	GM (BT gene)	Pleased the effects	Doe's not mind, if not a food material
Tomato	Companies	Longer shelf life	GM (suppressor gene)	Pleased the effects	Doe's not mind?
Rice	USDA	Lodging resistant etc. Anti-weed	Mutation Selection from resources	Good achievements (Still under research)	Good results, so far (Perhaps no problem)
Wheat	USDA,University	Disease resistance	Translocation (Induced or spontaneous)	No problem	Good results, so far
Barley	University Companies	Metabolite control Metabolite control	Mutation Mutation	No problem No problem	Good results, so far Good results, so far

USDA : United States Department of Agriculture
GM : Genetic modification, in these cases gene introduction by transformation

in the US genetic resources database, a trend of differentiation into two separate streams among the crop species became clear as shown in the Table 2.

Strangely, in maize, soybean, cotton and in tomato, there were no registered mutant variety at all in the genetic resources database of the US, except for a few mutant lines in soybean for research work. On the other hand, in rice, wheat, barley and oat, GM technologies seemed not to be applied in breeding, but limited only for research work.

Another database available on internet

In this symposium, present state of mutant varieties in Japan was reported by Dr. Isao YAMAGUCHI. The Institute of Radiation Breeding may continue to be the information pivot in this field. It may be a complicated task to understand and screen the methodologies used to induce the mutant gene, e.g. if the mutant was developed by irradiation, or simply by tissue culture (somaclonal variation). But such information will be important both to see the trend of methodology and to show achievement in developing practical varieties.

Apart from such resources database, recently a database was opened on internet. It is a kind of encyclopedia type collection of information on radiation technologies, industrial, medical, agricultural and radiation facility fields, each based on reliable paper(s). The numbers of items totaled to more than 1,000, although in the mutation breeding field the number was less than 100. In the record data cited, most of them are of crop plant. In the animal kingdoms, mammals, fishes, insects etc., there are many research reports, but breeding by use of irradiation was very few, except for a few in silk worm.

Presently the language used in this database is only Japanese, but original English title of the papers based on and many tables and illustrations cited may be helpful even for foreigners. The internet address is also shown in the information sources of this paper.

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Information Sources (as of July 2001)

http://www-infocris.iaea.org/MVD/ : Mutant variety database, IAEA
http://www.ars.grin.gov/cgi-bin : Genetic resources database, USA
http://www.enn.com/indepth/gmfood/index.asp : About GM crops, USA
http://www.irb.affrc.go.jp : Home page, Inst. Rad. Breed., Japan
http://www.rada.or.jp : Radiation Tech. database, Japan
Mutation Breeding Newsletter No.1(1972) ~ No.44 (April 1999) : List of new mutant varieties
Mutation Breeding Review No.3 (1985) : List of mutant varieties
Mutation Breeding Review No.12 (2000) : List of mutant varieties

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データベースから見た世界の突然変異育種

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国連機関の一つであり原子力の平和利用の推進を任務とするIAEAは農業分野に関して同じく国連機関のFAOとの共同部門をIAEA本部に設置している。本報告は主に世界の突然変異育種の総括と普及・推進を担当しているこの部門から公表された資料に基づいた。これによると最初の登録公表品種は1934年に遡り，マラーやスタットラー等による放射線の突然変異誘発が報告された僅か数年後のことである。この場合は例外としても，X線のほかに第2次世界大戦後のガンマ線照射装置の普及により突然変異法による品種の数は大幅に増加した。突然変異法による品種の定義としてはIAEAでは直接利用，間接（交配）利用の両方ともに含めている。しかし，最近の米国の交配育種では突然変異育種法の成果として認識されないまま利用されIAEAに報告されないことが多い。これは一面では誘発変異体が普通の育種素材として認められていることを示している。最近インターネット上で公開されたIAEAのデータベースでは2001年1月の品種積算数は2200品種を越えている。突然変異法という技術の確立で，多くの好ましい特性を持つ品種が世界各地域で育成され，普及に移されている。

IAEAから公表されている突然変異品種をデータベースに組んで分析してみるといろいろとお国ぶりが読みとれてくる。品種数が最も多い中国では，最近では観賞用花き類に品種が出てきたが，以前は主に食用作物ばかりであった。一方，オランダとベルギーではこれと対照的に，最近になってビール醸造用の大麦の間接利用交配品種が出たが，従来はキク，ダリア，ストレプトカーパス等の観賞用の花き類が中心であった。また旧共産圏では雑種種子への照射が複数あった。しかし染色体の転座誘発などの特殊な目的以外では，雑種種子の使用は遺伝子の組み換えと新規の誘発変異との区別が困難であり好ましくない。また劣性遺伝子は既に不活性化されていることを考えると雑種の利用は標的遺伝子を少なくするという点でも好ましくない。

日本は最近では米国に追い越されたが，順位としてはまずまずの位置にある。今後は世界で数少なくなったガンマーフィールドでの緩照射や，再び脚光を浴びつつあるイオンビームによる成果を日本の特殊性として期待したい。

米国農務省の遺伝資源データベースの検索では小麦では既に報告されていた3品種のほかに29品種，大麦ではチェコスロバキアでのDiamantの後代を含め100品種以上がIAEAには未報告であった。また遺伝子組み込み育種の対象は企業主導型のトウモロコシ，大

豆，トマト，棉などであり，稲や大麦など突然変異育種で成果のある作物では，実用品種の育成にはGMO技術は使われていなかった。

国内の放射線技術データベースにもその農業利用分野に情報が入っている。このデータベースは工業利用，医学利用，放射線技術と農業利用の4分野がある。その中の育種分野では，発表されている品種数が100を越えている農作物の突然変異育種が主力となっている。

質疑応答

谷坂（京都大：座長）：このご講演では，データベースを良く見ていくと，間接利用の面などからして突然変異育種はもっと盛んであるようなお話しを伺ったものと思います。ところで，なぜトウモロコシでは変異体が出なかったのでしょうか。トウモロコシは他殖性作物ということで，突然変異育種には目がいかなかったというような事情が西側にあったのではないでしょうか。

天野：育種にたどり着く前の基礎研究の段階で，ウルチからモチへの変異に取り組んでいましたが，電離放射線によるモチの変異体でしっかりと生き残れる良いものが取れませんでした。それが20年間研究を行ってきた結論の一つです。1928年にスタッドラーが植物で突然変異の報告をしましたが，後に彼もその指摘をしていました。それが影響して，突然変異育種が一時アメリカでは止まっていたのではないでしょうか。なぜかわかりませんが，トウモロコシでは変異体の良いものが取れないのです。

なお，遺伝子の変性としては，ほとんどすべてが欠失型となりました。欠失型といっても染色体はつながるので，リペアのシステムはあるのでしょうが，タイミングがずれているのかもしれません。何か良いものが取れない理由があるものと思いますが，研究を行っていません。

福井（阪大）：トウモロコシで変異体が取れないことについてですが，グラハム・モアーなんかが，それぞれのシリアルのゲノムを見ていったときに，4倍体起源ではないかという案を出しています。そのあたりが関係するのではないかと思いましたが，いかがでしょうか。

天野：私が最初に聞いたのは，染色体数はイネが20で，トウモロコシは10ということで2倍体と思っていました。私は，そこのところよりも，リペア系が要因ではないかと思っています。イネでもオオムギでもγ線照射による遺伝子変異としてポイントミューテーションと思われるもの，例えば中間型のリーキータイプのミューテーションが出ます。ところがトウモロコシでは，γ線照射によって，いまだに良いものが取れていません。ただし，化学変異を使うと，いくらでも取ることができます。たぶん，シングルベースペアのエクスチェンジのミュータントと思いますが，電離放射線はトウモロコシと非常に相性が悪いというのが現実のところであると思っています。