Current Status and Research Directions of Induced Mutation Application to Seed Crops Improvement in Vietnam

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Abstract

Nuclear techniques and chemical mutagens have been applied in Vietnam since the 1970's in order to improve seed crops as rice, soybean, maize, groundnut, many mutant varieties were approved as national varieties and some promising regional lines. Main direction and methods using in varietal improvement in Vietnam were exploitation of gene resources, using genetic methods consisting of hybridization, mutation, gene transformation to create crops having high yield, good quality, tolerance to diseases and adverse conditions. Up to the year 2007, according to preliminary statistics, in Vietnam 50 mutant varieties were created (as IAEA database, having 43 mutant varieties created, Vietnam is being the ninth of mutant breeding' achievement record in the world). Among of those, seed crops occupied 47 varieties: rice was 32 varieties, soybean was 11, maize was 2, and peanut was 2. At AGI 17 rice mutant varieties, 11 mutant varieties of soybean were bred and approved by Ministry of Agriculture and RD as national and regional varieties. At present, about 15 % of Vietnam rice area annually cultivated by mutant varieties, some best mutant varieties become one of the top 5 varieties for export and grown recently more than 300,000 ha per year in South, more than 50% of soybean cultivated area occupies by mutants contributing worthily to increasing cereal productivity of Vietnam.

Introduction

For a long history, Vietnam still had lacked a food, in period of 1970 – 1980, every year Vietnam had to import 2 – 3 million tons of cereals for the need of domestic consumptions.

After 20 years of Renovation (1988 – 2007), production of major cereals (rice, corn, soybean, groundnut) have been increased by 2.5 – 4.0 times, yield – 2 times, consequently national food security has been already established in the whole country. In 2007 Vietnam exported 4.3 million tons of rice keeping the world's second-largest exporter. However Vietnam still had to import about 0.7 million tons of maize, 2.5 million tons of soybean. (**Table 1**). To solve with this problem Vietnam has many kinds of means to promote cereals production, in that genetic improvement is considered as a first priority.

Brief history of mutation breeding in Vietnam

Nuclear techniques and chemical mutagens have been applied in Vietnam since the 1970's in order to improve crops. Many mutant varieties have been planted in field of large area. A lot of agriculture research institutes have cooperated with Vietnam Atomic Energy Commission (VAEC), International Atomic Energy Agency (IAEA) and other organizations to conduct mutation breeding in varieties such as rice, maize, soybean, groundnut and other ornamental and fruit plants, many of which were approved as national varieties and some promising regional lines. Among them Agricultural Genetics Institute (AGI) is a specific research center, which used to be one of the earliest institutes applying nuclear techniques to create new mutant varieties by gamma rays, X rays, and the other mutagenic chemicals and had many successes in this field. Main methods using in varietal improvement in Vietnam were exploitation of gene resources, using and genetic methods consisting of hybridization, mutation, gene transformation to create crops having high yield, good quality, tolerance to diseases and unsuitable climate conditions.

Up to the year 2007, according to preliminary statistic, in Vietnam 50 mutant varieties were created (as IAEA database, having 43 mutant varieties created in 2007 Vietnam is being the ninth of mutant breeding achievement record in the world), among of those seed crops occupied 47 varieties, rice occupied 32 varieties, soybean 11, maize 2 and peanut 2 (**Table 2**, **Appendix 1**).

Table 1. Some achievements in seed crops production after 20-years of Renovation (1988 – 2007) in Vietnam (*)

Seed Crops	Years	Total area (Thous. Ha)	Production (mill. tons)	Yiel (tons/ha)
Paddy rice	1985	5,603.9	15.8	2.78
	2007	7,210.0	35.994	4.99
Corn	1985	587.1	0.86	1.47
	2007	1,067.9	4.11	3.58
Soybean	1985	102.1	0.0791	0.78
	2007	190.1	0.2755	1.47
Groundnut	1985	212.7	0.2024	0.95
	2007	254.6	0.5051	1.98

(*) Source: State staticstical office 1985 - 2007

Table 2. Mutation derived varieties in the world (FAO-IAEA Mutant Variety Database, 2007, Apr.)

Country	Var. No	Rank	Country	Var. No	Rank
China	638	1	Brazil	36	13
India	272	2	Slovakia	35	14
Japan	232	3	UK	34	15
Russia+USSR	214	4	Bangladesh	27	16
Netherland	176	5	Sweden	26	17
Germany	176	6	Cote d'voi	26	17
USA	128	7	Guyana	26	17
France	43	8	Belgium	23	20
Vietnam	42 (50*)	9	Iraq	23	20
Pakistan	42	9	Denmark	22	22
Bulgaria	38	11	Austria	21	23
Canada	37	12	Rep/of Korea	19	24

(*) Remark: By Vietnam primary data

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Main achievements of nuclear application on mutation breeding in rice in Vietnam

Agricultural Genetics Institute (AGI) is a specific research center, one of the institutes apply early nuclear techniques to create new mutant varieties by gamma rays, X rays, and the other mutagenic chemicals and we had many successes in this field (**Appendix 1**)

Rice is the major cereal and the staple food in Vietnam 75% starch quantities for daily meals of almost people. At present, 4.5-5 million tones of normal white rice from the total production 36 million tons are exported, reached up to 1.5 billion USD (2007), mainly for Asian market with competitive price (ca. ~260-275 USD/t), and very limited quantities of rice with high quality and glutinous rice (<100.000 t) are included, but mainly for Japan market with increasing price (>420 USD/T).

The National Strategy Project on Rice Breeding is identified for yield and quality improvement to increase the income of rice producing farmers and export price to support the food security of the country with the increasing population (ca. 90 mil. persons) and to meet the higher requirements of many markets opened in Europe, Middle East and Africa.

Recent development of combination of nuclear techniques with biotechnology, known as *in vitro* mutagenesis and manipulation, and molecular markers has been effectively introduced for the induction of new and novel types of crop varieties.

The used materials were local lines (Cuom, Chiem bau, Tam thom, Nang thom, Nang huong, Te etc.) and the varieties presently used in the crop productivity (C4-63, A8, CR203, Khang dan, IR64, IR50404). The treatment methods were dry seeds with different radiation doses (Gamma ray, X-ray with 80, 100, 150, 200, 250Gy, useful doses were 100, 120, 200Gy); the others were germinated seeds with radiation doses of 20, 30, 40, 80Gy, useful doses were 30, 40, 60Gy).

In the decades of 1980-1990 of last century, AGI has created 17 national, regional mutant varieties, particularly the varieties having high yield and good resistance. DT17 and DT18 are submerged tolerance, salinity tolerance varieties comprising CM-1, CM-2, CM-3, cold tolerance varieties including DT-10, DT11, DT13, Khang dan Dot bien, DT37, DT3 having short growth, good quality, high yield and good resistance. In 2007, licence of mutant variety Khang Dan Dot bien (origin is KD18) was successfully transferred on Centural Seed Company. These varieties are preponderance in the Northern provinces and every year occupies about 40% of cultivated area (about (0.4 million ha per year).

In present, some of the best mutant varieties such as VND95-19, VND95-20, VND404, VND99-3, TNDB-100, THDB created by Institute of Agricultural Sciences for Southern Vietnam (IAS) and Cuu Long Delta Rice Research Institute (CLRRI) have been released for large-scale production in Mekong River Delta. Nowadays, these varieties were planted in 3.0 million hectares , counted for 10 – 15 per cent annual area. Among of those, VND95-20 has become one of the top 5 varieties for export and grown recently more than 300,000 ha per year in Southern Vietnam. Due to significant contribution for socio-economic development, **VND95-20** was awarded National Prize of Science & Technology by Vietnam Government.

In combination with hybridization method, some mutants gave promising recombinants in aroma, tolerance to BPH, Grassy Stunt Virus (GSV) & Ragged Stunt Virus (RSV) diseases. Selected varieties as VN 121, VN 124, VN24-4 are released into production in recent time [5,6].

Problems need to be stressed for research directions on rice

In Vietnam, the most constraints to the crop production, especially rice, fruits, legumes by far caused by biotic, particularly brown plant hopper, and abiotic stresses such as salinity, drought, acid-sulphate and other adversely environmental factors.

The elite rice varieties such as Khang Dan, Q5, Tam thom, Basmati have been popularly cultivated in Vietnam because of their stability of high yields, very wide adaptability. But the major constrains facing production of the varieties for both domestic and export demand are their low quality not only in cooking, edibility and nutrition but also in grain appearance.

To raise grain quality it is necessary to improve related characteristics, such as: cooking and edibility relating to amylose content, gelatinization temperature; nutrition relating to protein content; grain appearance relating to grain length, grain width, width-length ratio and translucency of endosperm.

The major constrains of grain quality can be overcome by radiation-induced mutation.

To improve plant type of traditional aromatic rice varieties it is mainly necessary to reduce their long duration of growth and responses to N-fertilizers, to increase grain yield. To remove their photoperiod-sensitivity, that partly relates to so long durations of growth, going along with maintain and improve their characteristics in aroma and grain quality both for domestic consumptions and export demands.

The Program entitled "*Radiation-induced aromatic rice varieties for high yield and good quality*" has been started June 2000, applying irradiation treatments with γ rays of ^{60}Co on traditional aromatic rice cultivars with some special characters, e.g. grains translucent, fragrant, fine, rich in protein but short and small; good tolerance, but without improved plant type, e.g. over 160 cm in height, lodging, 160-180 days in growth duration and low yield (<3 t/ha),… Moreover, the conventional crossings are quite limited for this group of rice varieties.

Therefore in this cycle our program during 5 years to come is focused on some following pivotal tasks as following:

- Development of rice varieties with high yield (>5.5 t/ha), short growth duration (ca. 90 - 120 days), good quality for export and domestic consumptions at high grades.
- Improvement of drought, salinity and disease tolerance of rice varieties.

The doses of irradiation of 60-90Gy were applied for germinated seeds of Aromatic Tam and Basmati 370 (from Pakistan), respectively, since 2001-2002 from broad spectra of variants a lot of novel mutants have successfully been selected for improved criteria, such as: no photoperiodic sensitivity (suitable with any crop seasons in the year), short growth duration (90-100 days), stiff and short plant type (90-110 cm),… and yields more than twice higher than original variety (6-7,5 t/ha).

During 5 years of selections and multi-regional trials, some pure line mutants (at M8-M10) with high quality grains meeting export demands of aromatic rice. Over 4 crop seasons in many provinces both in Mekong and Red River Deltas, their consistency has been established.

In Northern Vietnam, some pure mutant lines of Tam Aromatic rice has been isolated and tested in National Program as follows : HP-101 (HN-PN-103-1), HN-PN-103-3, HN-PN-103-4 (selected in Institute of Food & Cereal Crops) and TL4 (selected in Institute of Agricultural Genetics); produced at large scales in 3 provinces.

In Southern Vietnam, 5 pure mutantlines: TDS3 (Tám 28-9-4), E 4, E 6 and BDS have been enlarged areas of cultivation in provinces: Soc trang, Dong nai, Long an, Daknong, An giang,… They are well improved in grain quality, e.g. length (>7-7,5 mm), quite translucent and their fragrance is still maintained as required for export. Highest yields in large scaled-production are recorded in An Giang (7,5-10 t/ha) and approved by almost rice farmers at Field Symposia (9/2004, 1/2005, particularly in January and June 2006), and appreciated by breeding experts.

Main achievements of nuclear application on soybean mutation breeding in Vietnam

In Vietnam, soybean (*Glycine max* (L.) Merr.), an important food and industrial crop, provides the protein need and oil for human being, the food for animals and the materials for industry. Although spreading of soybean cultivated area in Vietnam still has a large potency, but it increases quite slowly. In 2007, the soybean planted area was reached

only to 190,100 ha with the yield of 1,47 ton/ha (63.2% average world yield), and the soybean produce was 275.5 thousand tons, meanwhile in 2007, Vietnam had to import 2.5 million tons (equivalent of dried seed) from foreign countries. Up to 2015, Vietnam intends to import 3.5 – 4.0 million tons/year of soybean.

Thus the problem, which made by the fact of production and market to Vietnamese soybean breeders was selecting and creating soybean varieties with short growth duration (75-100 days), high yield (2.0 -3.5 tons/ha), good seed quality, tolerant to drought, resistant to diseases, adapted to crop pattern and ecological regions in the whole country.

In Vietnam, Tran Dinh Long (1990) selected M-103 soybean variety by using EI. At AGI, the researcher group, leaded by Mai Quang Vinh et al (1985, 1987, 1990, 1995, 1998, 2000, 2002, 2004, 2007), has been carrying out the research on the application of induced mutation and bred 9 mutant soybean varieties and 10 other promising varieties and lines.

From 1980 to 2006, 31 varieties and lines were used, consisting 6 local cultivars: Coc chum, Quang hoa, Dau lang, Cuc luc ngan, Xanh bac ha, Cuu long Delta. 7 bred or introduced varieties: DT-70, DT-76, DT-94, K7002, K6871, IS-011, DT-80. 11 mutant varieties and lines: M-103, DT-83, DT-84, DT-90, DT-94, DT-95, DT-96, DT-99, MV1, MV4, AK04… Treatment Methods: Dried seeds treated with Gamma ray Co^{60} with doses of 70, 100, 150, 180, 200, 220Gy, Chemical mutagens: EI, DES, EMI, NMU, DNMU, DEU with concentrations of 0.02, 0.04, 0.06, 0.08% in 2, 4, 6 and 8 hours; combining treatment by Gamma ray Co^{60} with dose of 100Gy and chemical mutagen Ethyleninine 0.008, 0.02 and 0.05%. Treated in *pre-embryo phase and zygote cell in flowering phase* by Gamma ray Co^{60} with the doses of 100, 200 300Gy.

In twenty years (1987 – 2007), 4 National, 5 regional production, 10 promising mutant and cross-mutant soybean varieties and many other valuable soybean lines, selected by AGI, were adopted by Scientific Committee of MARD as national varieties, among of those DT84, DT99, DT96 are 3 varieties occupied the largest-scale of soybean cultivated area thanks to their grown ability of three crops per year, broad adaptation, good tolerance to hot, cold temperature and good resistance to diseases. At present Vietnamese mutant soybean varieties occupy more than 50% of soybean cultivated area in the whole country (more than 100 thousands ha per year), contributing worthily to increasing soybean productivity of Vietnam from 0.78 tons/ha (1985) to 1.47 tons/ha (2007), cultivated area from 102.1 thousands ha (1985) to 190.1 thousands ha (2007), production increased three times, resulting in the productivity of Vietnamese soybean is ranked as the highest in South-East Asian countries (**Table 3**).

In Vietnam, after the results of using induced mutation combined with crossing for soybean varietal improvement, the mutation breeding works could:

1) Improve yield component factors:

Mutant variety DT-83 have the yield higher than that of the original variety Coc chum 70%, plant higher than 50%.

Mutant variety DT-84 have the yield higher than that of its parent 30-40%.

Mutant variety DT-95 have the yield higher than that of original variety AK-04 15-20%.

2) Improve seed quality and color.

Change from blue seed to yellow seed: DT-83 and DT-95 varieties have yellow seed meanwhile original varieties Coc chum and AK-04 have blue seed.

Seed size: P1000 seeds of DT-83 variety heavier than that of Coc chum 60% (86 gr. to 138 gr) the mutant variety DT2003 (Line NC12, improved from DT-83) has P1000 seeds of 160gr. The DT-90 variety has P1000 seed heavier than that of its parent 20-30%.

Protein content increased +6.46 to -7.7% in mutant lines from Coc chum, 41.15% instead 39.50%.

Improve the cracked seed coat character in D.3/33 (DT-80 x DT-76) and breed DT-84 with less cracked seed coat character.

Table 3. The characteristics of mutant soybean varieties and hybrid recognized in 1987-2008

Variety & line	Growth duration (days)	Plant height (cm)	Flower color	Average yield (ton/ha)	P1000 seed (gr.)	Seed color	Crop
DT-83 (*)	90	40-50	Violet	13-27	138	Yellow	Sp-Sm
Cochum(origin)	88		Violet	8-18	86	Blue	Sp-Sm
DT-84 (*)	85-90	45-50	Violet	15-35	160-180	Yellow	Sp-Sm-W
ĐT-80 (origin)	85-105	40-60	Violet	14-27	120-140	Yellow	Sp-W
ĐT-76 (ĐH4)(Con)	89	40-45	Violet	12-25	180-200	Yellow	Sm
DT-90 (*)	95-100	45-50	White	15-30	180-200	Yellow	Sp-Sm-W
K.7002x	90-95	45-50	White	15-30	150-180	Yellow	Sp-W
Coc chum	88	45-50	Violet	8-18	90	Blue	Sp-Sm
DT94 (**) (DT83 x DT84)	90-95	45-55	Violet	15-30	150-160	Yellow	Sp-Sm-W
DT-95 (*)	90-103	50-80	Violet	15-30	160	Yellow	Sp-Sm-W
AK-04 (origin)	95-100	40-55	Violet	15-20	150-180	Blue	Sp-Sm-W
DT-96 (**) (DT84 x DT90)	95-98	45-50	Violet	15-30	180	Yellow	Sp-Sm-W
DT-99 (*) (IS-011 x Cuc)	70-80	35-45	Violet	13-24	150	Yellow	Sp-Sm-W
AK-06 (DT.55)	85-95	40-60	White	17-25	165-180	Yellow	Sp-Sm-W
ĐT-74 (origin)	95-100	40-60	White	15-23	160-170	Yellow	Sp-W
DT2001(**) (DT84 x DT83)	88-100	45-70	Violet	18-40	170	Yellow	Sp-Sm-W
DT2003(*) DT83 (origin)	88-98	40-60	Violet	18-35	160	Yellow	Sp-Sm-W
DT2008 (*) D.158 (origin)	100-120	50-80	Violet	25-40	160	Yellow	Sp-Sm-W

Note: (*) Variety acquired directly from mutation - (**) Hybrid variety from mutant parent
Origin: Original variety; Con: Control variety; Sp: Spring; Sm: Summer; W: Winter

3) Improve temperature and disease resistance:

The varieties DT-84, DT-90, DT-94, DT-95, DT-99, AK06 (DT55): can be cultivated in 3 crops/year in Northern provinces of Vietnam by combining heat and cold tolerance of their parent.

AK-06 variety can be planted in 3 crops in North Vietnam after improving non-tolerance to heat character of the original variety V-74.

Mutant DT95 variety showed resistance to 7/10 trains of rush (*Phakopsora pachirhizi* Sydow), it's AK04 (origine) are susceptible to rush [7].

Mutant DT2008 showed high resistance to 3 kinds of diseases: rush, downy mildew, bacterial posture and drought tolerance.

4) Improve growth duration:

Mutant line DT95/049 (DT95B) of DT-95 variety shortened 8 days of growth duration.

From the practical research on mutation process and mutant soybean variety breeding at AGI, we come to some conclusions as following [3,4]:

The dry seeds newly harvested, stored less 3 months, having high survival rate, can tolerate to high dose or concentration of mutagens treated. They can generate more variations/mutants than the long-term stored seeds.

The genetic sensibility ability of the local varieties is higher than that of the selected and introduced varieties. Mutant frequency of local varieties usually was lower.

It is possible to use cytological methods, meioses index, chromosomal aberration frequency combined with physiological methods (germination rate, survival rate, chlorophyll variation frequency, optimal concentration and dose of treatment) to obtain the most useful mutation spectrum.

The effective concentrations of mutagen: EI-0.02-0.04%; NMU, NDMU: 0.06%; EMS, DEU, DES: 0.02-0.06% in 6-8 hours pH: 6 or 7, doses of radiation: 15-18Gy. Especially the treatment with EI (concentration 0.02-0.04%) combined with gamma ray 10Gy can give many valuable mutations in soybean.

The use of induced mutation can improve some economic and morphological characters in soybean, and improve economic characters of local varieties in keeping valuable characters of the original varieties.

Some mutant soybean varieties selected by VAGI which are widely applied in Vietnam:

DT-84: National, famous Vietnam soybean mutant, created by Gamma rays Co^{60}- 18Gy + F3 (DT80/DH4) adopted by MARD in 1994, Nowaday, DT84 have occupied 40% of 180,000 ha soybean areas of Vietnam and 80 - 90% soybean areas of many north provinces. Grow duration: 84 – 90 days, Yield: 1.8 – 3.5 tons/ha, protein content: 41%, wide adaptability, hot and cold tolerance, can be cultivated in 3 crops/year. DT84 was awarded national prize of Science & Technology VIFOTEC – 2005.

DT96: National variety, hybrid between two mutants (DT90/DT84), moderate drought tolerant, rush resistance, wide adaptability, suitable cultivated in 3 crops/year, growth duration: 88 – 100 days, yield: 1.8 – 3.6 tons/ha, high protein content (43 – 45%), DT96 was adopted by MARD in 2004.

DT2008: Newly selected, prospective variety, created by gamma rays Co^{60}- 18Gy + F4 (DT2001/IS10), drought tolerant, thermo-tolerant, resistant to rush, rush, downy mildew, bacterial posture. wide adaptability, suitable cultivated in 3 crops/year, grow duration: 110 - 120 days, high-yielding: 2.5 – 4.0 tons/ha.

Conclusion and Suggestions

After more than 30 years of close cooperation with IAEA, FAO and other foreign organizations, Vietnam recorded remarkable achievements in application of induced mutation breeding for seed crops improvement. About a 50 mutant varieties were created, among of those seed crops occupied 47 varieties (rice was 32 varieties, soybean - 11, maize - 2 and peanut - 2). These varieties occupy more than 50% of cultivated area of Vietnam mutant soybean and 15 % by mutant rice, contributing significantly to increasing cereal productivity of Vietnam.

Our research experienced that improvement of seed crops by inducing mutation, especially by radiation mutation breeding was effective method. In the coming years plant breeding directions will be close combination between conventional (mutation, hybridization) with modern biotechnology methods to reach the goal increase of plant breeding effective, to serve a The National Strategy Project on Food Security.

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APPENDIX

Apendix 1. Mutant varieties released by Agricultural Genetics Institute (AGI) and other Organization up to 2007

Plant species	Mutation breeding cultivars		
	AGI	AGI +other	Other
Rice (Oryza sativa L.) 32 cultivars	DT10, DT11, DT33, DT17, DT50, CL8, CL9, DT21, DT22, Mutant Khang dan , DT38, CM1, CM6, MT4, MT6, DB250, DB2 (17)	A20, Mutant Tam thom (2)	VND95-20, VND95-19, VND99-3, VND95-26, VN4, TNDB, 6B, OM2118, NN22-98, TNDB100, THDB, ST3 Luc do (Red rice), ST3 Luc tim (Violet rice) (13)
Soybean (Glycine max.) 11 cultivars	DT84, DT90, DT96, DT99, DT94, DT95, DT83, DT2001, S-31 (9)	DT55 (AK06) (1)	M103 (1)
Maize (Zea mays L.)	DT6, DT8 (2)		
Groundnut (Arachis hypogea L.) 2 cultivars	DT332 (1)		B5000 (1)
Indian Jujube (Ziziphus manritiana L.) 2 cultivars			Dao tien, Ma hong (2)
Peppermint (Mentha varvensis L.) 1 cultivars	TN8 (1)		
Total: 50 cultivars	30	3	17

Appendix 2. Vietnam new mutant varieties and their cultural area (ha)

No	Variety	Organization	Origin	Mutagen	Certificate	Cultural area (ha)
Rice						
1	DT10	(AGI)	C4-63	200Gy + 0,025% NEU	NV, 1990	1,000,000 (1990 to present)
2	DT11	(AGI)	C4-63	20Kr + 0,025% NEU	NV, 1995	100,000(1995 to 2000)
3	A20	(AGI)	A8	0,015% NMU	NV, 1993	100,000 (1993 to present)
4	CM1	(AGI)	Chiem bau	200Gy	NV, 1999	1,000 ha/5 years
5	CM6	(AGI)	Chiem bau	200Gy	RV, 2000	1,000 ha/5 years
6	DT33	(AGI)	CR 203	200Gy	NV, 1994	200,000 ha (1994 to present)
8	DT38	(AGI)	KD 18	200Gy	RV,2007	500 ha/year
9	Khang dan mutant	(AGI)	KD 18	100-200Gy	NV, 2007	20,000 ha/year
10	Tam thom mutant	(AGI)	Tam thom	100-200Gy	NV, 2000	5,000ha/5 years
11	CL9	(AGI)	IR64/KD18	150Gy	NV, 2006	10,000 ha/2 years
12	CL8	(AGI)	DT20	150Gy	PV	5 000 ha
13	VND95-20	(IASS)	IR64	GI	NV,	900,000 ha/3 years
14	TNDB-100	(IASS)	Nang huong	GI	NV,	300,000 ha/3 years
15	VND 99-3	(IASS)	-	GI	NV,	45,000 ha, 60 bill. VND /3 years
16	OM 2118	(IASS)	-	200Gy	NV,	50,000 ha/3 years
17	ST3 red	CNT, HCM city	-	GI +H	PV	-
18	ST3 purple	CNT, HCM city	-	GI + H	PV	-
Maizes						
1	DT6	(AGI)	Mehico variety	GI + chemical	NV, 1990	50,000 ha (1990-2000)
2	DT8	(AGI)	DT6	GI + chemical	RV,1996	5,000 ha (1994-2004)
Soybeans						
1	DT84	(AGI)	DT80/ DH4	GI + H	NV, 1995	70,000 ha/year
2	DT90	(AGI)	K7002/Cuc	GI + H	NV, 2002	3,000 ha/year
3	DT96	(AGI)	DT84/DT90	GI + H	NV, 2004	5,000 ha/year
4	M103	(VASI)	DH4	EI	NV, 1990	1,000 ha/year
5	AK06 (DT55)	AGI, HAU, VASI	V74	GI	NV, 2000	1,800 ha/year
6	DT99	(AGI)	IS-011/Cuc	GI + H	RV,2003	11,000 ha/year
7	DT94	(AGI)	DT83/DT84	GI + H	RV	400 ha/year
8	DT95	(AGI)	AK04	GI	RV,1995	800 ha/year
9	DT83	(AGI)	coc chum variety	EI – 0.04%	RV,1990	50 ha/year
10	DT2001	(AGI)	DT84/DT83	GI + H	RV, 2007	500 ha/year
Peanut						
1	DT332	(AGI)	-	GI	RV, 1998	200 ha/year

Note: NV- National variety; RV- regional variety; PV- potential variety
Gamma irradiation – GI; hybridization – H