Mutation Breeding of Rice for the Sustainable Agriculture in Vietnam

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Introduction

In Vietnam, rice plays an important role for national food security and political stability. Rice also has a direct effect on social security because it is consumed by nearly 89 million of the total population and an important source of income for more than 90 million people living in agricultural and rural areas. Rice is the country's main crop, accounting for more than 90% of total cereal productivity. Rice production in 2015 reached 45 million tons, and it is 0.3% higher than in 2014. Vietnam is one of the top 5 countries that studies reveal will be severely impacted by climate change. A rise in sea level of 1 meter will inundate about 5,000 square kilometers (km^2) of the Red River Delta and 15,000–20,000km^2 of the Mekong River Delta, reducing total rice production in Vietnam by about 5 million tons. Bad harvests, natural calamities, floods, and pests and diseases will also occur more often. Ensuring domestic food security has thus become a national objective that requires long-term strategies and policies, especially for the protection of the agricultural land area. Vietnam does not only seek to achieve domestic food security but it also plays an important role in the international rice market, and consequently, in the food security of the international community.

Despite of a decrease in rice land area, rice production has been rising due to rapid yield growth. This in turn has been driven by irrigation and land development, together with technological change. In 2009, Vietnam had nearly 7.4 million hectares (ha) of rice lands, which declined to 2 million ha in 2015 (Ministry of Agriculture and Rural Development, 2015). However, rice productivity increased from 39,5 million tons in 2009 to more than 45 million tons in 2015. This was a remarkable achievement due to the application of advanced science and technology such as the introduction of different rice varieties, new production models, and an efficient irrigation system. Post harvest losses have also been reduced greatly due to the mechanization of rice harvesting and drying, and soil improvement.

Mutation Breeding in Vietnam

At present, about 15% of rice production area is covered annually by mutant varieties in Vietnam. Great achievement by the use of nuclear techniques and related biotechniques. More than 55 mutant varieties were developed, in which most of varieties are cereal crops, especially rice.

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, Bac thom). The treatment methods were dry seeds with different radiation doses (Gamma ray, X-ray with 80, 100, 150, 200, 250 Gy, useful doses were 100, 120, 200 Gy); the others were germinated seeds with radiation doses of 20, 30, 40, 80 Gy, useful doses were 30, 40, 60 Gy).

Since the 1990s, the Agricultural Genetics Institute (AGI), Vietnam Academy of Agricultural Sciences (VAAS), has been engaged in R&D activities and contributed much to the technology transfer to the agricultural sector of Vietnam. Mutation breeding is one of the major fields of institute in crop improvement, in which the biggest accomplishments have been achieved in the development of mutation varieties for crops production. Before 2000, objective of mutation breeding is often quantity of yield variety. One very interesting example from AGI is DT10 mutant variety which has been certified as national variety in 1990 due to the high performance, good tolerant to harmful condition. This variety is available in rice more than 25 years and now this is still disseminating in some specific location. This variety covers the area around 1.0 mil. ha in agriculture production. After success of mutant variety DT10, scientists from AGI released series of mutant varieties (20 mutant varieties) and satisfied production demand.

In the South Vietnam, mutation induction has been carried out mostly in Cuulong Rice Research Institute and Institute of Agriculture South Science (IASS). These institutions have also succeeded in the mutation breeding by the use of nuclear techniques. Over the past decade, the institutes have developed eight excellent mutant varieties with high yielding, improved quality, disease resistance, tolerance to pest and lodging resistance. One of these excellent mutant varieties (VND9s-20) which has been certified as national variety in 1999 became one of the top five varieties for rice production. It covered 300 thousand ha per year in south of Vietnam, due to its high yielding, good quality and tolerance to brown plant hopper. Not only has this variety been widely cultivated in the low lands, but also expanded to the high lands and remote mountain areas, where poor farmers are benefiting from growing it.

The great support from the Vietnamese Government makes the application of nuclear techniques in food and agriculture so successful. Due to the excellent performance of the mutant rice varieties mentioned above, some of these mutant varieties were adopted for the national strategy program of "Eradicate hunger and alleviate poverty" in different areas, particularly for central highland region, where there are many ethnic minorities living in remote mountain areas. Most of the eight mutant varieties have shown out-standing performance under local production conditions.

Release of new mutant rice for large scales of production

Recently, beside of yield varieties, scientists has been concentrating creation of new variety having good performance on quality (aroma, protein, amylose content, component of quality), as well as tolerance to harmful condition of environment such as salinity, cold or high temperature, drought, lodging variety and so on. Mutation breeding is powerful tool for rice breeding improvement.

During 2008 - 2017, groups of rice breeders continue effective collaborations for pure line selections under field trials of rice mutants and their crossings with high quality and tolerance in Red River Delta (North Vietnam) and Mekong River Delta (South Vietnam). There are ten outstanding new varieties have been certified as new varieties and ongoing projects to enlarge mutation varieties in different provinces (Table 1).

Khang dan mutant variety has been transferred the trading rightcopyright from AGI to the seed company since 2008 after it was certified as national variety. With some advantages, the area covered with this variety is around 300 thousands ha/year in north Vietnam. In 2012, the seed company is rewarded the national prize for Khang dan mutant variety due to the leading area for agriculture production of this variety.

ĐB5, ĐB6 mutant varieties have high yield, good tolerant to pest and disease. OM 2496 has high productivity, aroma and salinity tolerance. Nam dinh 5 variety has Quality, aroma and high yield. PD2 is glutinous rice and photo sensitiveness. It has high yield and aroma. P6 mutant has short growth duration (85-90 days in summer season) and high temperature tolerant. Mutant rice varieties DT39 Quelam, CNC11 have improved in productivity for high yield, better quality and tolerant to bacterial leaf blight. Moreover, DT39 gave high nutrition content such as iron, zinc, Kali and Maggie in comparison to origin variety.

Mutant rice varieties DT39 Quelam and CNC11 has been transferred the trading rightcopyright from AGI to the seed company.

Table 1. Leading mutant varieties in rice production in Vietnam (duration 2008-2015).

No	Variety	Year of certify	Dominant characters	Area of production/year (ha)
1	Khangdan mutant	2008	High yield, good tolerant to pest and disease	300,000
2	ĐB5	2008	High yield, good tolerant to pest and disease	5,000
3	ĐB6	2008	High yield, good tolerant to pest and disease	5,000
4	OM 2496	2009	High productivity, Aroma, Salinity tolerance	3000
5	PD2	2010	Glutinous rice, photo sensitiveness, high yield, aroma	10,000
6	P6 mutant	2011	Short growth duration 85-90 days in summer season, high temperature tolerant	15,000
7	Nam dinh 5	2012	Quality, aroma, high yield	3,500
8	ĐB15	2012	High yield, good tolerant to pest and disease	600
9	DT39 Que lam	2013	Quality, high protein, high yield, resistant to leaf blight	800
10	CNC11	2015	Quality, high protein, high yield, resistant to leaf blight	300

Applications of gamma rays irradiation and marker assisted selection for improving of rice varieties for the sustainable agriculture.

Climate change creates adverse conditions for rice production in rice growing regions. For adaptation to mentioned challenges, cultivation of varieties resistant to biotic and abiotic stresses is required.

In present, the application of irradiated techniques and biotechnology in rice breeding has focused on some major traits, such as high yield, short duration, good quality, bacterial leaf blight resistance, blast resistance and salt tolerance.

In 2013, dry seeds of three varieties were irradiated with 300 grey of Cobalt-60 gamma rays. Among them, BT62.1 was resistant to bacterial leaf blight (carrying *Xa7, Xa21* genes), P5.3 was resistant to blast (carrying *Piz* gene), and BT3.1 was salt tolerant variety (carrying *saltol* gene). All of these varieties have low yielding. Purpose of irradiation is improvement of yield. M1 and M2 plants of these varieties were evaluated for mutant characteristics. We expect to get the mutant lines not only have resistance to diseases but also have high yield, short duration, and good quality.

In 2014, M3 and M4 progenies of these varieties were used for marker assisted selection (MAS) and inoculation in the green house to select elite lines resistant to bacterial leaf blight resistance, blast resistance and salt tolerance. Twenty M4 mutant lines (from M4.1 to M4.20) retained as short duration, good quality, bacterial leaf blight resistance, blast resistance or salt tolerance as original varieties but they have the higher yield than the original ones.

In 2015, these lines are evaluated the agronomic and biological traits as well as resistance characters in field condition (narrow scale). The results showed that: 6 promising mutant lines were selected (2 mutant lines showed high resistance to the BB pathogen, 2 lines resisted the BL pathogen and 2 lines showed high salt tolerance in the field. The promising mutant line, DT80 carrying *saltol* gene and can withstand salinity of 0,6%. DT80 was evaluated in salinity field of the Nam Dinh province in spring season 2015.

In 2016, DT80 mutant line was evaluated the agronomic and biological traits as well as tolerant characters in field condition (narrow scale) and send the National testing Center. Beside of this activity, promising lines should be evaluated in different local conditions for evaluation of wide adaptability of new variety and evaluate the response of the farmer. The result of this evaluation indicated that DT80 mutant variety have improved in productivity for high yield (Potential yield: 6,8 - 7 ton/ha), better quality (amyloze contents: 14%), short growth duration (105-110 days in summer season), medium plant height (112 cm), Wide adaptation and easily cultivation. This new mutant variety were evaluated with some major pests and disease and the evaluation in the field showed that DT80 were affected by these biotic and abiotic stresses in the majority of harmful levels from 1-3 points.

DT80 was sent to The National Testing Center for Crops to test for Value of Cultivation and Use of crop (VCU) 3 seasons and Distinctness, Uniformity and Stability of crop (DUS) 2 seasons.

DT80 mutant variety has been transferred the trading right from AGI to the Thanh hoa seed company in November, 2016. In 2017 it registered as new variety by MARD.

Results of irradiation ion beam on rice breeding

Carbon ion beam have been recently considered as potential mutagens. A characteristic feature of ion beams is their ability to deposit high energy on a target, densely and locally. Rice seeds were treated with Carbon ion radiation (40, 60, 80 and 100 Gy) by AVF-Cyclotron at the Japan Atomic Energy Research Institute (JAERI), Takasaki, Japan and were planted and selected at the Agricultural Genetics Institute. There are some results of carbon ion Beam irradiation up to now.

Table 2. Overview irradiation data.

Varieties	Time	Dose
Bac thom and Khang dan	6/2010	40Gy and 60Gy
CMBT and BLBT	3/2013	40Gy and 60Gy
DT80, DT82, DT86, T5, TBR2 and RVT6	1/2015	60Gy and 80Gy
BC/6 and P12	6/2015	40Gy, 60Gy, 80Gy and 100Gy
ĐB2, KN6, BH9	6/2016	40Gy, 60Gy, 80Gy and 100Gy

Results of carbon ion beam irradiation on Bac thom and Khang dan

There are many types of variations in M2 generation from irradiated Bacthom and Khang dan. Four promising mutants were selected from Khang dan in which two lines came from dose of 40Gy and two other mutant lines were derived from dose 60 Gy. Most of the mutant lines express higher yield than the original variety and better resistant to pests and diseases. However, the objective of the project is to increase yield and to obtain good quality rice variety, therefore the research is concentrated in Bacthom variety. Selection process was conducted according to better agronomic traits; short grow duration, high yield and purity of mutant lines in the M4 and M5 generations. The mutant lines were grown and evaluated similar to the M5 and M6 but in the expanded testing area and perform in some different locations to assess purity, growth and development capacity, as well as yield and resistance to pests and diseases. The promising lines will be chosen for further research. Result indicated in the table 1 and 2 below. In M7 generation of Bacthom mutant variety showed that grow duration of some mutant lines (M7-2, M7-6 and M7-8) were similar to control; meanwhile some mutant line indicated short grow duration than the origin such as M7-4; M7-3. In M7 population, purity of 3 mutant lines M7-3, M7-4 and M7-5 were in level 1 better than the origin in level 5 as well as M7-2, M7-6 and M7-8. However, purity level of mutant line can be improved by selection process in further generation. Panicle length is also one of component of yield performance of variety. Most of mutant lines have panicle length that is longer than the control of Bacthom variety. That mean of most mutant lines may have higher yield compare to original Bacthom variety.

Table 3. Biological and agricultural characteristics of 6 Bacthom mutant lines in M7 (summer season 2013).

Lines	Growth duration (day)	Plant height (cm)	Flowering duration (points)	Plant hardness (points)	Panicle length (cm)	Purity (points)
BT (Cont.)	107	108.0	5	3	21.5	5
M7-2	107	115.6	5	3	25.8	5
M7-3	104	114.4	5	1	23.6	1
M7-4	102	117.2	5	3	24.5	1
M7-5	105	108.2	5	1	22.1	1
M7-6	106	109.6	5	3	22.4	5
M7-8	108	102.8	5	3	24.2	5

- Plant hardness: *1-Very hard, 3-Hard, 5-Medium hard, 7-Weak hard, 9-Weak hard.*
- Flowering duration: *1-Focus (≤ 3 days), 5-Medium (4-7 days), 7-Long (≥7 days)*
- Purity: *1-High (different trait ratio <0,25%), 5-Medium (different trait ratio: 0,25-1%), 9-Low (different trait ratio > 1%).*

With regards to the grain yield component of mutant lines in the M7 generation showed a significant difference compare with the control for full seed per panicle the highest were obtained at M7-4 and M7-8 lines and showed significant difference from other lines (table 2). This resulting in potential yield of M7-4 and M7-8 were higher than that of original and other lines with 9.63 tons/ha and 12.48 tons/ha. These other mutant lines performed grain yield higher than original variety except M7-6 which was 5.34 ton/ha. However, one elite mutant to be selected will not only depend on the yield performance character but also on the cooking quality and aroma characteristic of the variety.

Table 4. The grain yield components of 6 mutant lines of mutant Bacthom in M7 (Summer season 2013).

Lines	No. of panicle /hill	No. of seeds /panicle	No. of full seed /panicle	Weight of 1000 seeds (gr)	Potential yield (ton/ha)
BT (Cont.)	5.1	140.5	130.9	19.6	5.50
M7-2	5.3	177.6	159.3	22.1	7.84
M7-3	5.2	182.2	160.4	19.8	6.94
M7-4	5.8	212.4	197.7	20.0	9.63
M7-5	6.0	132.7	119.3	19.5	5.86
M7-6	5.5	127.3	118.5	19.5	5.34
M7-8	6.2	257.9	236.1	20.3	12.48

Cooking quality is main objective of the breeding improvement. Six mutant lines of Bacthom were tested in room condition for aroma, softness, stickiness, and taste to evaluate the quality of selected mutant lines in comparison to original variety.. The result of this experiment indicated that M7-2; M7-3; M7-6 and M7-8 have cooking qualities similar to the original variety Bacthom, meanwhile M7-4 and M7-8 indicated dry and hard when cooked even M7-4 and M7-8 but have highest grain yield.

Results of carbon ion beam irradiation on CMBT and BLBT

Ion beam irradiation 3/2013: The variable new mutant lines were screened and evaluated in M2 generation. (selected lines with short growing period, medium plant height, tillering ability, a number of seeds per panicle is higher than that of variety control. Specially, selected lines reveals small tillering angle, this is characteristic need to be improved from original lines). Selection process was conducted according to better agronomic traits; short grow duration, high yield and purity of mutant lines in the M3 and M4 generations.

Screening of mutant lines in M5 and M6 generation. In this period, agrobiological characteristics and tolerance traits is being tested in the field conditions (narrow scale). MAS was applied to identify the target genes. The prospective lines in M5 generation to be continued in varietal testing system for assessment of the agro -biological characteristics: field grain yield and grain quality towards approval as national varieties. Five mutant lines (two from CMBT, three from BLBT) with high potential yield and good agronomic traits were selected

Based on agronomic traits in fields, test in greenhouse and MAS in lab, 14 promising mutant lines in M5 generation were selected: 5 mutant lines from CMBT and 9 mutant lines from BLBT.

The results showed that 4 promissing lines (BL.1,2,6,7) have a growth duration is shorter and number of fulled seed is much higher than that of control. So that these lines obtained the higher yield than control variety (Table 9).

The results showed that 2 promissing lines (CM.3,4) have a growth duration is shorter and number of fulled seed is much higher than that of control. So that these lines obtained the higher yield (7.5 ton/ha) than control variety (Table 5).

In 2015 spring season, the total of 6 promissing mutant lines were obtained. These line will be selected in 2016 for evaluating the agronomic traits and resistance to pests and diseases.

Table 5. Agronomic traits and yield potential of BB mutant lines in M5 from BLBT (Spring season, 2015).

No	Mutant lines	Duration of growth (days)	Height of plant (cm)	Number of panicle/ plant	Panicle exertion (cm)	Number of fulled seed	Weight of 1000 grains (gr)	Potential yield (ton/ha)
Cont.	BLBT	130	109	6.5	2.3	184.7	22.3	5.7
1	**BL.1**	129	95	8.0	3.0	219.0	19.8	6.9
2	**BL.2**	128	95	8.0	3.2	236.7	20.1	7.2
3	BL.3	132	95	5.0	4.2	167.7	19.5	6.5
4	BL.4	130	95	7.0	3.0	192.3	20.2	5.9
5	BL.5	127	100	7.0	0.8	180.0	21.2	5.6
6	**BL.6**	125	100	7.0	1.7	257.7	21.5	7.5
7	**BL.7**	130	105	6.5	0.6	276.9	21.0	7.1
8	BL.8	129	100	5.8	0.9	242.0	21.4	6.1
9	BL.9	125	102	6.0	0.5	261.3	21.4	6.4

Table 6. Agronomic traits and grain yield components of Salinity tolerance mutant lines in M5 from CMBT (Spring season, 2015).

No	Mutant lines	Duration of growth (days)	Height of plant (cm)	Number of panicle/ plant	Panicle exertion (cm)	Number of fulled seed	Weight of 1000 grains (gr)	Potential yeild (ton/ha)
Cont.	CMBT	128	111	6.0	2.5	159.5	22.2	5.5
1	CM.1	128	105	8.0	3.5	183.0	20.3	5.9
2	CM.2	130	105	8.0	1.3	183.3	20.1	6.4
3	**CM.3**	129	100	8.0	-0.5	248.0	20.8	**7.5**
4	**CM.4**	130	100	8.0	-0.7	251.0	20.5	7.1
5	CM.5	129	100	7.0	5.7	145.3	21.3	6.7

Table 7. Agronomic traits and grain yield components of promising mutant lines (summer season, 2016).

No	Mutant lines	Duration of growth (days)	Height of plant (cm)	Number of panicle/ plant	Panicle exertion (cm)	Number of fulled seed	Weight of 1000 grains (gr)	Potential yeild (ton/ha)
Cont.	BLBT	105	110	5.5	2.3	145.7	22.5	5.3
1	BL.1	102	98	5.8	3.0	179.0	20.0	6.5
2	BL.2	108	100	6.1	3.2	186.7	20.1	6.8
6	BL.6	105	102	6.8	2.7	217.5	21.3	**7.5**
7	BL.7	103	110	6.5	**0.3**	176.9	21.0	6.1
3	CM.3	107	108	7.0	**0**	178.0	20.5	6.5
4	CM.4	105	109	6.5	**0.2**	175.0	20.6	6.1
Cont.	CMBT	128	109	6.0	2.5	159.5	22.0	5.5

The results of evaluating the agronomic trait in the field (Table 11) showed that these lines have a shorter duration, with higher production in comparison with control. Three mutant lines: BL7, CM.3, CM.4 were high yield, but their panicle exertion is very short (0-0.3cm). This reason make these lines can increase higher empty seed ratio for reducing the yield. Out of which, the promissing BL6 line revealed hard stem hardness, can resistance with abiotic and biotic stresses. Next, these lines will be adapted in different rice ecosystem to production expanding and sent to The National Testing Center for Crops to test for Value of Cultivation and Use of crop.

Table 8. Summary results of carbon ion beam irradiation (From 1/2015).

Variety	**Dose**	**M1** Sterility	**M2** variation	**M3** variation	**M4** (mutant lines)	**M5** (Promissing line)
DT80	60Gy	83%	15	25	5	0
	80Gy	86%	25	37	8	0
DT82	**60Gy**	**89%**	**10**	**15**	**12**	**8**
	80Gy	91%	20	18	5	0
DT86	60Gy	91%	26	20	8	0
	80Gy	91%	30	18	9	4
	100Gy	95%	18	24	9	6
T5	**60Gy**	**87%**	**9**	**16**	**12**	**7**
	80Gy	88%	15	21	5	0
TBR2	60Gy	87%	29	32	9	0
	80Gy	88%	5	0	0	0
RVT6	60Gy	85%	31	25	5	3
	80Gy	92%	45	18	6	3
Total			**278**	**269**	**93**	**31**

Results of carbon ion beam irradiation from 2015 to 2017

The variable new mutant lines were screened and evaluated from M2 to M5 generation. We selected lines with short growing period, medium plant height, tillering ability, a number of seeds per panicle is higher than that of variety control. The results in table 7 showed that: 278 mutant individual in M2 generation were selected in 2015. In 2016, 269 mutant individual in M3 generation and 93 mutant lines in M4 generation were selected. In 2017, based on agronomic traits in fields, 31 promising mutant lines in M5 generation were selected: 18 promising lines from 60 Gy, 7 promising lines from 80 Gy and 6 lines at 100 Gy.

In 2016, 56 mutant individual in M2 generation were selected with short growing period, medium plant height, tillering ability, a number of seeds per panicle is higher than that of variety control. In 2017, Set of 102 mutant lines were obtained in M3 generation, 39 mutant lines in M4 generation were selected. The results showed that (Table 8): 17 mutant lines were selected from 60 Gy, 7 mutant lines from 80 Gy and 15 mutant lines at 100 Gy.

Table 9. Summary results of carbon ion beam irradiation (From 6/2015).

Time irradiation	**Variety**	**Dose**	**M1** Sterility	**M2** variation	**M3** variation	**M4** (mutant lines)
6/2015	BC/6	40Gy	75%	0	0	0
		60Gy	91%	15	26	17
		80Gy	91%	5	12	0
		100Gy	95%	3	9	0
	P12	40Gy	68%	5	0	0
		60Gy	91%	12	18	0
		80Gy	91%	10	23	7
		100Gy	95%	6	14	15
Total				**56**	**102**	**39**

Table 10. Summary results of carbon ion beam irradiation (From 6/2016).

Variety	**Dose**	**Germination***	**M1** Sterility	**M2** variation
BH9	40Gy	100%	75%	
	60Gy	100%	91%	31
	80Gy	99%	91%	23
	100Gy	97%	95%	14
KN6	40Gy	100%	65%	
	60Gy	98%	91%	11
	80Gy	100%	91%	22
	100Gy	100%	95%	24
ĐB2	60Gy	100%	91%	
	80Gy		91%	
	100Gy		95%	20

From irradiated time 6/2016: 145 mutant individual in M2 generation were selected in 2017. Among that: 44 mutant lines were selected from 60Gy, 45 mutant lines from 80Gy and 58 mutant lines from 100Gy.

The promising mutant line with some improved traits such as: light aroma, softer endosperm, good tillering ability, big and longer seed size, more grain number per panicle....comparing to original variety. Thus, our research was focused on database of 5 target genes regulated these features as in table below:

Through sequence and BLASTN, total of 24 point mutants were identified in target genes (as in table).

Table 11. Results of study to clarify mutation related to high yield and good quality Material of study.

No.	Name	Features
1	Original variety (DT82)	BLB resistance, low yield, tillering ability (4-5 tillers), plant height (113-115cm), dark green leaf, small seed, dark yellow husk seed
2	Ppromising line (60Gy)	BLB resistance, improved yield, better tillering (8-10 tillers), plant height (120 cm), light green leaf, better quality, big and long seed, light yellow husk seed

Table 12. Target gene information.

No.	Gene name	Regulation	Gene features
1	Os08g0424500	Betaine aldehyde dehydrogenase, Rice fragrance	Chr.8 (21703754:21707360), including 13 exons
2	Os06g0133000	Glutinous endosperm	Chr.6 (1929936:1935488), including 15 exons
3	Os03g0171600	Leaf senescence, seed size and grain number	Chr.3 (4284298:4286750) including 1 exon
4	Os07g0261200	Grain number, plant height, and heading date 7	Chr.7 (9173610:91755560) including 2 exons
5	Os03g0203200	Shoot branching	Chr.3 (5895977:5897579), including 2 exons

Table 13. Identified point mutations in target genes.

Gene	Number of mutant	Location of mutants
Os08g0424500	6	Exon 1 (40, 41, 42, 47, 48); exon 12 (121)
Os06g0133000	6	Exon 3 (33, 34, 35, 70); exon 4 (15); exon 9 (115)
Os03g0171600	5	426, 615, 621, 1017, 1263
Os07g0261200	4	Exon 1 (73, 253); exon 2 (32, 36)
Os03g0203200	3	Exon 2 (24, 98, 401)
Total	**24**	

Conclusion

- The dose of 60 Gy is effective for screening good trait mutants
- To be need further trial to assess the efficiency of dose 80Gy and 100Gy
- Mutations conducted from ion beam were almost point mutations

Work plan

- Testing promising lines in different ecological zones
- Continue screening mutation lines to select the good and stable lines
- Repeat the irradiation with range of doses to performed the most effective dose for mutation breeding.

Conclusion

Successful story of mutation plant breeding in Vietnam is contributed from political support by Vietnamese government for mutation plant breeding research such as international organization such as FAO/IAEA, through project IAEA/VIE/05/13/14 from 1997-2003 and Ministry of science and Technology Foundation was supported by Program: Applied research and development of energy technologies; code: KC05.09/11-15 from 2012-2015. Beside of this from 2008, Vietnam became official member of Forum for Nuclear Cooperation in Asia (FNCA). Scientists from different institutions have chance to go abroad and attend training course, scientific symposium and workshop, or to exchange information and experiences with scientists working in mutation breeding.

It's clear that mutation induction nowadays is one of powerful tool for crops improvement in Vietnam. Mutant rice varieties from institutions contribute to increase of rice performance and productivity in recent years. This is confirmed that Vietnam Government has been concentrating research and development of the activities on nuclear techniques in agriculture. Beside of that farmers also benefit from scientific research activities.