Pak. J. Bot., 39(7): 2457-2461, 2007.

SUSTAINABLE RICE PRODUCTION THROUGH THE USE OF MUTATION BREEDING

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Abstract

The most significant achievements in rice breeding at Nuclear Institute of Agriculture (NIA), Tando Jam, Pakistan through mutagenesis are the evolution of four high yielding and better quality varieties. These varieties have been released by the Provincial Seed Council, Government of Sindh for general cultivation. The first rice variety "Shadab" was released in 1987 by treating the seeds of IR6 with chemical mutagen, ethyl methane sulphonate (EMS 0.5%). Its yield potential is 7 tones/ha and is endowed with high yield and fine grain quality. Shadab is being cultivated on more than 0.06 million hectares and has contributed 21 million US$ as additional income in provincial economy. The 2nd variety in the series was "Shua-92" evolved by irradiating the seeds of IR8 with 15 Gy fast neutrons. In addition to high yield and fine grain quality, Shua-92 also possesses salt tolerance and was released in 1993. The yield potential of Shua-92 is 8.5 tones/ha and it is being cultivated over an area of 0.16 million hectares in the Sindh province. The cultivation of Shua-92 has contributed an additional income of 223 million US$ in provincial economy. The 3rd variety was developed by exposing the seeds of rice variety Jajai-77 (aromatic) to 200 Gy gamma rays and Sugdasi type "Khushboo-95" a short stature endowed with high yield was released in 1996. Due to its short stature, it escapes from lodging and produces higher yields with better inputs. The yield potential of Khushboo-95 is 5.5 tones/ha and it occupies 0.02 million hectares and has provided an additional income of 8 million US$ to farmers. The 4th rice variety "Sarshar" was developed by irradiating the seeds of IR8 with 150 Gy gamma rays. It is a high yielding variety with fine grain quality characteristics and is endowed with tolerance to shattering and insect pests. The yield potential of Sarshar is 9.5 tones/ha and it occupies an area of 0.08 million hectares. It has contributed an additional income of 32 million US$ to farmers. The rice varieties developed by NIA, Tando Jam, have significantly enhanced the yield per hectare and uplifted the socio-economic conditions of the farmers in Sindh and Balochistan provinces of Pakistan.

Introduction

Rice has been a popular subject to mutagenesis because it is the world's leading food crop. Being diploid species, maximum genetic variability is available for selection in M_2 generation. Induced mutations have thus played a vital role for the improvement of rice by developing a large number of semi-dwarf and high yielding varieties around the world (McKenzie & Rutger, 1986; Micke *et al.,* 1987; Maluszynski *et al.,* 1991; Qayoom *et al.*, 2000; Baloch *et al.,* 2002 and Baloch *et al.,* 2003). In the province of Sindh, rice is being cultivated over an area of 2.23 million ha of which about 45% is under non-aromatic varieties. After Green Revolution in the sixties of 20th century, maximum area under rice came under cultivation of short statured varieties IR6 and IR8. Inspite of their high yield, the varieties had not their quality good enough to meet the consumer's demands. Similarly aromatic varieties also remained under cultivation though in lesser quantities, but have the major draw back of their long duration and lodging susceptibility. We therefore initiated our mutation breeding programme with the objectives of improving the quality of non-aromatic IRRI varieties and improving the plant architecture of locally cultivated aromatic varieties, for earliness and lodging resistance.

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Material and Methods

Mutation breeding in rice has been carried out at Nuclear Institute of Agriculture (NIA), Tando Jam, Pakistan with the objectives of improving yield, earliness, grain quality, plant architecture and tolerance to salinity and insect pests. Both physical (gamma rays and fast neutrons) and chemical mutagenesis (ethyl methane sulphonate) were applied to seeds of *IR6*, *IR8*, and Jajai 77. Selection in M_2 was mainly done for traits of agronomic significance. Most of the mutations were deleterious and discarded. Mutants selected for various traits were confirmed in M_3 generation and those showing phenotypic stability were evaluated in M_4. Further evaluation was carried out in subsequent generations. Only productive mutants were promoted in regional and national yield trials covering different ecological niches. Mutants with desired characters were released as new varieties while those with marker characters were included in the germplasm.

The released varieties were inducted in the cropping system of province over the years. There has been a gradual increase in the area and productivity of the province. In each year the estimates of additional benefits due to cropping of new varieties was worked out using the following formula.

Additional Yield = Variety Yield (t/ha) – Average Yield of province (t/ha)
Economic Impact = Additional Yield (t/ha) x Area under variety (m ha) x Rate (US$)

Results and Discussion

Shadab: The rice variety Shadab, evolved by treating the seeds of *IR6* 0.5%, with chemical mutagen, ethyl methane sulphonate (EMS 0.5%), approved for release in 1987 for general cultivation in the Sindh province of Pakistan, is endowed with high grain yield and quality characters. It has more translucent and extra long grain (7.52 mm) as compared with its mother variety *IR6* (6.91 mm). The cooking quality of rice is influenced by amylose content of the grain (Tables 1 and 5). Shadab contains high amylose content (30.7 %) as compared to IR6 (30.1 %) due to which it exhibits high volume expansion and elongation ratio. Its yield potential is 7 tones/ha and endowed with fine grain quality. Shadab is being cultivated on more than 0.06 million hectares and has contributed 21 million US$ as additional income in provincial economy.

Shua-92: Shua-92, evolved by irradiating the seeds of *IR8* with 15 Gy fast neutrons was approved for release as a new variety in 1993 for general cultivation in the Sindh province. It has high paddy yield, good grain quality and appreciable salt tolerance (Table 2). The yield potential of Shua-92 is 7.83 tones/ha and is being cultivated over an area of 0.16 million hectares in the Sindh province. The cultivation of Shua-92 has contributed an additional income of 223 million US$ in provincial economy (Table 5). It has more number of panicles (18.3), filled grains per panicle (168), L/B ratio of milled grain (3.46), head rice % (64.20) as compared with its mother variety *IR8* (Table 2). The cooking quality of rice is influenced by amylase and chalkiness content of the grain. Shua-92 contains high amylase content (26.7%), less chalkiness (1.85%), protein (7.76%) as compared to IR8 (Tables 2 and 5). It has long and slender grain with significant reduction in chalkiness. Shua-92 is a great breakthrough, because in Sindh Province salinity poses serious limitations in maintaining and enhancing paddy yield and this variety can grow well even in ECe 7.11 to 8.0 mmho/cm, which is above threshold range for rice (ECe 3.0 to 3.6 mmho/cm).

Table 1. Comparative performance of Shadab with its mother variety (IR6).

Characteristics	Shadab	IR6	% Increase over parent
Potential paddy yield (tones/ha)	7.59	7.67	--
Average productive tillers	20.72	18.88	10
Filled grains per panicle	163.60	156.20	05
L/B ratio of milled grain (mm)	4.08	3.50	17
Head rice (%)	69.95	55.95	25
Amylose content (%)	30.70	30.10	02
Protein content (%)	9.56	9.11	05
Proportionate elongation	1.82	1.49	22

Table 2. Comparative performance of Shua-92 with its mother variety IR8.

Characteristics	Shua-92	IR8	% Increase over parent
Potential paddy yield (tones/ha)	8.5	7.38	15
Average productive tillers	18.3	14.5	26
Filled grain per panicle	168	138	22
L/B ratio of milled grain (mm)	3.46	2.61	33
Head rice (%)	64.20	33.55	91
Chalkiness (%)	1.85	45.81	-96
Amylose content (%)	26.7	26.2	02
Protein content (%)	7.76	7.12	09
Proportionate elongation	1.65	1.43	15

Table 3. Comparative performance of Khushboo-95 with its mother variety Jajai 77.

Characteristics	Khushboo-95	Jajai-77	% Increase over parent
Potential paddy yield (tones/ha)	5.5	2.5	120
Average productive tillers	14.45	10.68	35
Filled grain per panicle	148	88	68
L/B ratio of milled grain (mm)	3.24	3.07	06
Head rice (%)	44.0	41.5	06
Amylose content (%)	20.80	19.81	05
Chalkiness (%)	25.0	68.83	-64
Proportionate elongation	1.55	1.50	03

Table 4. Comparative performance of Sarshar with its mother variety IR8.

Characteristics	Sarshar	IR8	% Increase over parent
Potential paddy yield (tones/ha)	9.5	7.38	29
Average productive tillers	20.2	14.5	39
Filled grain per panicle	156	138	13
L/B ratio of milled grain (mm)	3.29	2.61	26
Head rice (%)	42.5	33.55	27
Chalkiness (%)	1.62	45.81	-96
Amylose content (%)	27.2	26.2	04
Protein content (%)	7.22	7.12	01
Proportionate elongation	1.62	1.43	13

Table 5. Economic impact and additional benefits (US$ million) of rice mutant varieties since their release.

	Shadab (1987)	Shua-92 (1993)	Khushboo-95 (1996)	Sarshar (2001)	Total
Area under cultivation in Sindh (m ha)	0.06	0.16	0.02	0.08	0.32
Yield (kg/ha)	3316	4018	2598	4178	
Additional Yield (%)	25	38	21	42	
Economic impact since release (US$ million)	21	223	8	32	284
Area under rice cultivation in Pakistan				2.2252	12%
Area under rice cultivation in Sindh				0.4883	54%
Area under cultivation of NIA rice varieties Tandojam				0.27	

Source: Agriculture Statistics of Pakistan 2004-2005

Khushboo-95: Khushboo-95 is an aromatic variety developed by exposing the seeds of local tall rice variety Jajai-77 to 200 Gy Gamma rays. The mother variety due to its tall habit (170 cm) was lodging susceptible and could not respond to higher doses of nitrogenous fertilizers. Through mutagenic application, the mutant Khushboo-95 has been isolated with relatively reduced plant height (130 cm) and has better response to N fertilization, thus producing almost double the yield of mother variety. It was approved for release as a new variety in 1996 for Sindh province. Khushboo-95 possesses more number of productive tillers (14.45), higher number of filled grains (148), better L/B ratio (3.24) and good recovery of head (44%) as compared with Jajai 77. Khushboo-95 has best cooking quality because it has less chalkiness (25%) and high content of amylose content (20.80%) as compared to its parent variety Jajai 77 (68.83) and (19.81) respectively, (Table 3). The yield potential of Khushboo-95 is 5.5 tones/ha and it occupies 0.02 million hectares and has provided an additional income of 8 million US$ to farmers (Table 5). It has a comparatively short stature with high grain yield while its mother variety is tall and produce low yield.

Sarshar: The Sarshar variety, evolved by irradiating the seed of IR8 with 150 Gy gamma rays was approved for general cultivation in Sindh province in 2001. This variety is not only high yielding but also characterized with resistance to insect pests and diseases, such as leaf folder, white backed plant hopper (WBPH), rice stem borer (RSB), mealy bug (MB), brown spot, narrow brown leaf spot, glume discoloration and kernel smut. It is also resistant to shattering. The yield potential of Sarshar is 9.5 tones/ha and it occupies an area of 0.08 million hectares. it has contributed an additional income of 32 million US$ to farmers (Table 5). The quality characteristics of Sarshar are better than its parent variety IR8. It has long slender grain with minor chalkiness of 1.62% as compared to mother variety with 45.81%. It has 12%, 4% and 2% higher gel consistency, amylase, and protein % respectively than its mother variety *IR8.*

Our results are in agreement with the findings of rice workers around the world. Bari *et al*., (1981); Mustafa *et al*., (1997); Rutger (1983); Hu (1991); Malusyznski *et al*., (1986); Wen & Qw (1996); Baloch *et al.,* (1999); Baloch *et al.,* (2001a); Baloch *et al.,* (2001b); Baloch *et al*., (2004) and Baloch *et al.,* (2005) who have also used induced mutations to evolve high yielding mutant varieties of rice. On the basis of promising performance for desired agronomic traits, and has been released as rice varieties for general cultivation in Sindh.

Conclusion

The high yielding rice varieties with fine grain quality were developed from coarse and indigenous (sugdasi type) varieties through chemical mutagenesis, gamma rays and fast neutron. Except Shadab remaining varieties produced 15%, 120% and 29% higher paddy yield as compared to its parent and check varieties respectively. These rice varieties will contribute significantly towards income and increase in socio-economic uplift of the farming community in Pakistan.

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(Received for publication 14 February 2006)