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Assessment of the per se performance and genetic variability of grain quality traits of promising induced mutant lines in the M_3 generation of ADT 47 rice

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ABSTRACT

Present investigation was conducted on 83 selective mutants along with parent ADT (R) 47 aimed to study the milling and cooking quality characters. Among the mutants, six mutants viz., 200-84-69-10-11, 200-62-27-25-20, 200-72-6-28-39, 200-71-34-29-46, 250-28-62-27-21 and 250-6-38-29-16 were found to be desirable for both milling yield and head rice recovery than the parent. While ten mutants possessed short slender grains, three mutants each showed long slender and short bold grains. One mutant viz., 250-27-69-4-48 had higher linear elongation ratio and 37 mutants had less breadth wise elongation ratio. A total of 24 mutants registered higher volume expansion after cooking. Gel consistency alone showed moderate values for PCV and GCV while the rest of the traits had lower values. High heritability coupled with high genetic advance was observed for linear elongation ratio, breadth-wise elongation ratio, while moderate heritability coupled with high genetic advance was recorded for the traits head rice recovery, kernel breadth, L/B ratio and volume expansion ratio. This indicates the predominance of additive gene action in the inheritance of these characters. Therefore, these mutants can be utilized extensively in hybridization programs to isolate better quality rice selections which are the need of the hour and are chiefly preferred by the consumers.

Key words: *Rice mutants, quality parameters, genetic variability*

Rice is the most important staple food more than 2/3rd of the population throughout the world (Yang et al., 2013). Among cereals, estimating the grain qualities of rice has been given top priority (Dong et al., 2007), since rice is consumed as a whole grain, unlike other cereals, where primarily the flour is used. From the consumer point of view, endosperm appearance, size, shape, cooking and eating characteristics of grains are of great concern (Kumar et al., 1994). Major determinants of grain quality in rice particularly appearance, milling and cooking quality are important issues for the acceptance of the genotype/variety by the consumers. The presence of variations for such traits in the breeding material being handled offer scope for selection of lines with desired quality. The ADT (R) 47 rice, which is a popular variety in the region and also possesses good grain quality characteristics needs improvement as it is having certain drawbacks like extended duration to exactly fit in the first season, just exerted nature of the panicle and resistance to grain shattering during threshing. The main objective of the study was to isolate promising mutants with good grain quality traits in the M3 generation of the mutagens treated ADT (R) 47 were similar or higher than parent.

The genetically pure seeds of ADT (R) 47 Rice (*Oryza sativa* L.) variety were obtained from Tamil Nadu Rice Research Institute, Aduthurai of Tamil Nadu Agricultural University, Coimbatore. The seeds were irradiated with different doses (200, 250 and 300Gy) of gamma rays from ^{60}Co source from the Centre for Plant Breeding and Genetics, Coimbatore. For EMS treatment, healthy seeds were treated with varied concentrations *viz.*, 100, 120 and 140mM. The M_1 field experiment was carried out in the south farm, Tamil

Nadu Rice Research Institute, Aduthurai without replication. The M_1 plants were harvested separately and the plant progenies were raised in M_2 generation during November 2012. The primary panicle of individual M_1 plant was forwarded to M_2 as per plant to progeny method. A total of 600 M_2 families comprising of 100 per dose from Gamma and EMS treatments were evaluated based on seed fertility ratio. The progenies of the plants selected based on the formulated objectives in M_2 generation were sown in raised nursery beds along with control. The number of M_3 families evaluated are 51, 32 and 28 families respectively from gamma radiations at 200Gy, 250Gy and 300Gy and 31, 33 and 39 families respectively from 100mM, 120mM and 140mM EMS concentrations. Twenty five days after sowing, the seedlings of mutation generations *viz.*, M_1, M_2 and M_3 were transplanted to the main field with the single seedling per hill. Standard agronomic practices and plant protection measures were followed to raise a good crop. The spacing was maintained at 20cm (between the rows) and 10cm (between plant to plant) in the field.

Twelve grain quality parameters were analysed on the 83 individual mutants selected from mutagen treated ADT (R) 47 and their parent ADT (R) 47 in M3 generation. The selected plants belonged to different treatments *viz.,* 39, 15 and 10 from gamma irradiations at 200Gy, 250Gy and 300Gy respectively and six each from 100mM, 120mM and seven from 140mM EMS concentrations. Quality analysis of selected mutants was carried out at Grain Quality Lab, Plant Breeding and Genetics Unit, Tamil Nadu Rice Research Institute, Aduthurai. Milled rice was used to evaluate various cooking properties viz., Milling percentage (MY), Head Rice Recovery percentage (HRR), Kernel length (KL) (Rao et al., 2013), Kernel breadth (KB) (Rao et al., 2013), Kernel Length / Breadth ratio (L/B ratio) (Rao et al., 2013), Kernel length after cooking (KLAC) Azenz and Shafi (1996), Kernel breadth after cooking (KBAC), Linear Elongation Ratio (LER) (Juliano and Perez., 1984), Breadth wise Elongation Ratio (BER), Volume Expansion Ratio (VER) (Verghese, 1950), Gel Consistency (GC) Cagampang et al. (1973) and Gelatinization Temperature (GT) (IRRI, 1997). The gelatinization temperature was estimated based on the alkali spread value of the milled rice. The mean data for each character was subjected individually to statistical analysis. The analysis of variance was carried out as suggested by Panse and Sukhatme (1985), GCV and PCV by Burton and De Vane (1953) and heritability and genetic advance by Johnson et al. (1955).

Rice is the only cereal crop cooked and consumed mainly as whole grains, and quality considerations are much more important than for any other food crop (Hossain et al., 2009). Although production, harvesting and post harvest operations affect overall quality of milled rice, variety remains the most important determinant of market and end-use qualities. Desired quality in rice vary from one geographical region to another and consumers demand certain varieties and favour specific quality traits of milled rice for home cooking. A total of 83 individual mutants were selected based on per se performance, panicle exsertion, threshability and yield from M_3 families were evaluated for 12 quality parameters. List of mutants with superior grain quality characteristics in ADT (R) 47 at M_3 generation are furnished in Table1 and the results of genetic analysis are presented in Table 2.

The milling percentage of selective plants from M3 recorded the overall mean value of 61.2% and the values ranged from 55.08% (120-41-31-10-1) to 70.2% (250-28-62-27-21). The parent ADT (R) 47 recorded 66.96% milling yield. Seven mutants *viz.,* 200-84-69-10-11, 200-62-27-25-20, 200-72-6-28-39, 200-71-34-29-46, 200-91-13-40-25, 250-28-62-27-21 and 250-6-38-29-16 recorded significantly higher milling yield than the parent. The values of PCV (6.1%), GCV (5.2%) were low, heritability (72.71%) was high but genetic advance as per cent of mean was low (3.41%). Considering both milling yield and head rice recovery, six mutants *viz.*, 200-84-69-10-11, 200-62-27-25-20, 200-72-6-28-39, 200-71-34-29-46, 250-28-62-27-21 and 250-6-38-29-16 were found to be desirable than the parent ADT (R) 47. This is in accordance with the suggestion of Shobha Rani et al. (2002) to choose parents with high milling yield for producing progenies with high milling quality and head rice recovery.

The mean value of 53.74% with a range of 44.1% (200-83-52-11-30) to 65.8% (200-62-27-25-20) was recorded for HRR in the studied mutants. The parent had 55.3% HRR. Out of 83 mutants, 20 plants were found to be significantly superior to the parent. Of these, 4 mutants *viz.,* 200-62-27-25-20, 200-71-34-

Table 1. List of mutants with superior grain quality characteristics in ADT (R) 47 at M_3 generation

Mutants	MY (%)	HRR (%)	KL (mm)	KB (mm)	L/B ratio	KLAC (mm)	KBAC (mm)	LER	BER	VER	GC (mm)	ASV
200-84-69-10-11	69.71	57.80	5.30	1.80	2.94	7.00	2.50	1.32	1.39	4.50	90.00	5.00
200-62-27-25-20	69.08	65.80	5.50	1.90	2.89	6.00	2.10	1.09	1.11	4.00	104.00	5.00
200-72-6-28-39	68.52	56.00	5.00	1.90	2.63	7.00	2.60	1.40	1.37	4.20	86.00	4.00
200-71-34-29-46	67.39	61.20	5.40	2.00	2.70	7.00	2.70	1.30	1.35	4.30	113.00	5.00
250-27-69-4-48	60.69	53.70	5.70	2.10	2.71	9.00	2.30	1.58	1.10	4.30	48.00	5.00
250-22-20-21-36	55.32	46.90	6.00	2.00	3.00	8.50	2.80	1.42	1.40	4.00	90.00	4.00
250-8-28-26-4	61.98	54.50	6.50	1.90	3.42	9.10	2.40	1.40	1.26	4.60	80.00	5.00
250-28-62-27-21	70.20	59.30	6.30	2.00	3.15	8.60	2.60	1.37	1.30	4.20	84.00	5.00
250-6-38-29-16	67.53	56.40	5.50	1.90	2.89	7.00	2.80	1.27	1.47	4.60	89.00	5.00
300-20-13-15-21	58.87	54.60	5.00	2.00	2.50	6.00	2.10	1.20	1.05	4.00	115.00	4.00
120-34-24-32-10	60.35	52.70	5.70	1.80	3.17	7.50	2.50	1.32	1.39	4.70	76.00	4.00
Mean	61.20	53.74	5.41	1.95	2.79	7.03	2.48	1.30	1.28	4.16	86.52	4.51
SD	3.74	3.73	0.28	0.10	0.22	0.53	0.20	0.08	0.11	0.35	16.70	

MY-Milling yield, HRR-Head rice recovery, KL-Kernel length, KB-Kernel breath, L/B ratio-Length breath ratio, KLAC-Kernel length after cooking, KBAC-Kernel breath after cooking, LER-Linear elongation ratio, BER- Breathwise expansion ratio, VER-Volume expansion ratio, GC-Gel consistency and ASV-Alkali spreading value

Table 2. Estimation of genetic parameters for quality traits of selective mutants in M_3 generation of ADT (R) 47 rice

S. No.	Traits	PV	GV	PCV%	GCV%	h^2%	GA	GA %
1.	Milling yield	13.96	10.15	6.10	5.20	72.71	2.09	3.41
2.	Head Rice Recovery	16.16	13.50	7.46	6.82	83.54	6.91	12.84
3.	Kernel length	0.044	0.027	3.88	3.05	61.96	0.45	8.50
4.	Kernel breadth	0.010	0.010	5.09	5.01	97.02	0.26	13.41
5.	L/B ratio	0.038	0.036	7.03	6.80	93.69	0.42	15.38
6.	Kernel length after cooking	0.21	0.20	6.61	6.36	92.31	0.68	9.71
7.	Kernel breadth after cooking	0.03	0.03	7.41	7.39	99.50	0.23	9.45
8.	Linear elongation ratio	0.008	0.005	6.90	5.56	64.95	0.30	23.67
9.	Breadth wise expansion ratio	0.009	0.008	7.40	7.27	96.68	0.26	20.55
10.	Volume expansion ratio	0.15	0.14	9.78	9.24	89.41	0.66	16.31
11.	Gel consistency	269.02	264.69	18.31	18.17	98.38	2.92	3.26

29-46, 200-30-21-43-9 and 300-32-26-7-4 had > 60% head rice recovery. Low estimates of PCV (7.46%), GCV (6.82%), high heritability (83.54%) and moderate GA% of mean (12.84) was encountered. Shobha Rani (2003) noted that medium grain rice was more resistant to cracking than long-grain rice during milling, probably due to its more rounded and thicker grain shape compared to the slender-shaped grain of long-grain rice.

Kernel length exhibited a mean value of 5.41mm by ranging from 5.0mm to 6.5mm in the ADT (R) 47 mutants. The range at higher end is far above the parental mean of 5.4mm. Eight plants *viz.*, 200-40-32-6-49, 200-72-6-28-39, 200-59-31-32-10, 200-89-54-44-23, 200-48-16-51-36, 300-28-61-12-14, 300-20-13-15-21 and 140-83-48-16-28 possessed short kernels (5.0mm) and four plants *viz.*, 250-8-28-26-4 (6.5mm), 250-28-62-27-21 (6.3mm), 300-36-5-2-7 (6.2mm) and 250-22-20-21-36 (6.0mm) possessed long kernels. The trait exhibited low PCV (3.88%), GCV (3.05%), high heritability (61.96%) and low genetic advance as per cent of mean (8.5). In a study by Tuhina and Arshad (2009) on M_4 generation of three basmati rice varieties, Basmati 370 derived lines and Ranbir Basmati showed maximum kernel length in 30 kR gamma ray treatment. While in Saanwal Basmati, the kernel length progressively increased in 30 and 40 kR gamma ray dwarf mutants and EMS 0.5 % tillering mutants.

The kernel length and length breadth ratio decides the shape of the kernel. The parent ADT (R) 47 has medium slender grains. Among the various mutants evaluated in this study, ten mutants *viz.*, 200-96-71-2-59, 200-37-70-8-23, 200-73-16-21-42, 200-54-49-45-39, 200-79-46-48-51, 250-36-39-7-16, 140-8-16-21-27, 100-88-78-16-2, 120-70-15-27-18 and 140-29-93-26-37 possessed short slender grains. Three mutants *viz.*, 250-8-28-26-4, 250-28-62-27-21 and 300-36-5-2-7 had long slender grains. Another three mutants *viz.*, 200-48-16-51-36, 100-8-5-9-46 and 140-83-48-16-28 had short bold grains, while, the rest of 67 mutants possessed medium slender grains. Slender grains are preferred by people to consume rice as wholesome grain after cooking so that the appearance of cooked rice may look slender if breadth-wise expansion is less.

The bold rices are usually consumed as flour or by products. Krishnaveni and Niveditha (2014) isolated mutants with long bold grains at 20kR and 0.25% EMS treatments, long slender grains at 30kR + 0.25% and 0.3% EMS treatments in Akshaya rice variety. The trait kernel breadth ranged from 1.8mm (17 mutants) to 2.1mm (14 mutants) in 83 analysed plants with a mean of 1.95mm. The control ADT (R) 47 had a mean kernel breadth of 1.9 mm. Seventeen plants had significantly less kernel breadth than the parent. The PCV, GCV and GA as per cent of mean were found to be low but a high heritability of 97.02% was observed for this trait.

The trait L/B ratio registered a mean value of 2.79 in the mutants and it ranged from 2.38 (200-48-16-51-36, 140-83-48-16-28) to 3.44 (300-36-5-2-7). The L/B ratio of kernels in the parent was 2.84. The trait exhibited low PCV (7.03%), GCV (6.8%), high heritability (93.69%) and moderate GA as percent of mean (15.38). Bordoloi and Talukdar (1999) reported that mean L/B ratio increased in rice genotypes *viz.*, IR 50, IR 36, Culture1 and Govind when irradiated with 10, 20 and 30 kR gamma ray doses.

In the mutants studied, the trait kernel length after cooking recorded a mean of 7.03 mm and the trait ranged from 6.0mm (200-62-27-25-20, 200-55-34-36-28, and 300-20-13-15-21) to 9.1mm (250-8-28-26-4). Another mutant plant 250-27-69-4-48 recorded 9.0mm kernel length after cooking. The parental mean for this trait was 8.2mm and four mutants exceeded the parent for the trait. The PCV (6.61%), GCV (6.36%), and GA as per cent of mean (9.71%) were found to be low and heritability (92.3%) was found to be high.

The mean value of parent for kernel breadth after cooking was 2.80mm. In the mutants evaluated, this trait expressed a mean value of 2.48mm and ranged from 2.1mm (200-96-71-2-59, 200-80-73-16-6, 200-62-27-25-20, 300-29-6-9-9, 300-20-13-15-21) to 2.9mm (300-77-15-23-9 and 100-88-78-16-2). Barring eight plants all the mutants showed desirable values for this trait when compared to the parent. Low PCV (7.41%), GCV (7.39%), GA as per cent of mean (9.45) and a high heritability (99.5%) was noticed for the trait.

In the mutants, linear elongation ratio recorded a mean of 1.30 and fell in the range between 1.08 (300-36-5-2-7) and 1.58 (250-27-69-4-48). The control had a value of 1.52 and only one mutant exceeded the parent. Low estimates of PCV (6.9%), GCV (5.56%), high heritability (64.95%) and GA% of mean (23.6) was recorded. Kernel elongation is influenced by both genetic and environment factors, especially temperature at the time of ripening (Cruz et al., 1989). The ambient temperature of about 25°C during night at ripening has been found to be favourable. Maximum elongation was reported in grains that matured at these temperatures. Higher kernel length after cooking is a desirable trait as it decides the market acceptance and consumer preference. Among the 83 mutants, four plants *viz.*, 250-8-28-26-4, 250-27-69-4-48, 250-22-20-21-36 and 250-28-62-27-21 exceeded the parent (8.2mm) for kernel length after cooking. But the linear elongation ratio of all mutants was lesser than the parent (1.52) except one mutant *viz.*, 250-27-69-4-48 which recorded 9.0mm length after cooking and its linear elongation ratio was 1.58. A similar difference for highest grain elongation was recorded in D. Basumathi (3.3 mm) and least in Salem Sanna (0.4 mm) by Gangadharaiah et al. (2015) in traditional rice cultivars. Singh (2005) obtained two mutants PBM 1 and PBM 2 with significantly higher kernel elongation than Pusa Basmati 1. In a study with ten early mutants and the parent variety Samba Mahsuri, Kulkarni et al. (2000) reported that elongation ratio varied from 1.34 to 1.60. Mutants M-7 and M-20 had higher elongation ratio than the parent variety.

Increase in either length or breadth can occur depending on the increase in volume during cooking as and when water is absorbed. Generally, breadth wise increase upon cooking of rice is considered an undesirable trait, while high quality rice varieties are characterized and preferred based on increase in length during cooking with less breadth-wise expansion (Danbaba et al., 2011). Elongation of rice can be influenced by both the L/B ratio and the amylose contents (Danbaba et al., 2011). In breath wise expansion ratio, the mean of mutants was 1.28, while the mean of control was 1.33. The values of mutants ranged from 1.05 (300-20-13-15-21, 100-7-40-21-14, 140-83-48-16-28) to 1.50 (140-39-62-6-27). Thirty seven mutants recorded lower values than the parent. The trait exhibited low PCV (7.40%), GCV (7.27%), high heritability (96.68%) and high GA as per mean (20.55). Except eight mutants, all showed desirable values for kernel breadth after cooking compared to the parent (2.8mm). In general, minimum breadth-wise expansion ratio upon cooking is preferred by the consumers. In this study, thirty seven mutants recorded lower values than the parent (1.33) for this trait.

The mean of the mutants studied (4.16) were found to be on par with that of the parent (4.20) for volume expansion ratio. The values of mutants fell in the range between 3.1 (200-80-73-16-6, 200-66-62-22-28) to 4.7 (200-59-31-32-10, 250-46-9-13-56, 250-4-32-30-55, 120-34-24-32-10 and 140-57-77-9-32). A total of 24 mutants recorded higher values than the parent.

The estimates of PCV (9.78%) and GCV (9.24%) were found to be low. The heritability (89.41%) and GA as per of mean (16.31) were found to be high and moderate respectively. Volume expansion of cooked rice is another important parameter of consumer preference and higher values are preferred. A total of 24 mutants registered higher volume expansion after cooking over the parent. Higher volume expansion after cooking (4.7 times) were recorded by the mutants 200-59-31-32-10, 250-46-9-13-56, 250-4-32-30-55, 140-8-16-21-27 and 140-57-77-9-32. Banumathy (2001) reported that volume expansion is highly dependent on amylose content. Mishra et al. (2015) reported that the volume expansion ratio ranged from 3.25 to 3.55 in Ajay and Rajalaxmi hybrids.

Gel consistency of mutants in ADT (R) 47 showed a mean of 86.52mm and the values ranged from 44mm (250-45-33-17-2) to 119mm (200-38-8-7-56), while the parent had a mean gel consistency of 57.5mm. Barring seven plants, all the mutants had values above 60mm.

The estimates of PCV (18.31%) and GCV (18.17%) were moderate. The heritability (98.38%) was high but GA as percent of mean (3.26) was low. Gel consistency is the main factor that determines the texture namely softness or hardness of cooked rice. GC of *indica* rice varies from hard through medium and soft. Medium and soft gel consistency types of rice varieties/ hybrids are generally preferred. In the present study, all the mutants had soft rice with soft gel consistency except the mutants *viz.*, 200-91-13-40-25, 200-79-46-48-51, 250-27-69-4-48, 250-37-75-10-47, 250-45-33-17-2, 100-7-40-21-14 and 120-41-31-10-1 which possessed flaky rice with medium gel consistency. Shehata et al. (2009) observed that gel consistency of 10 mutants ranged from 80.51mm to 90.58mm.

The trait alkali spreading value of all mutants fell in the score of either 4 or 5 compared to that of the parent (score 4) which implies intermediate gelatinization temperature. Gelatinization temperature (Alkali Spreading Value) is the measure of cooking ease and is indexed by alkali digestibility test (Little et al., 1958). In the present study, all the mutant plants showed intermediate alkali spreading value. The intermediate rating (4-5) indicates medium disintegration and is classified as intermediate gelatinization temperature and is also highly desirable for quality grain (Bansal et al., 2006). All the quality characters studied revealed generally higher heritability estimates in broad sense exceeding 60 per cent in this study. Gel consistency alone showed moderate phenotypic and genotypic coefficient of variation and all other traits had lower values.

Mishra and Verma (2002) observed high heritable values for kernel length after cooking, kernel breadth after cooking, and kernel elongation. Krishnaveni et al. (2006) reported high heritability estimates for kernel length, kernel breadth, L/B ratio and alkali spreading value in a study involving 10 parents and 25 hybrids of aromatic rice. Shehzad et al. (2011) reported high GCV and moderate heritability for milling% in five mutant lines at M_6 to M_8 generations.

High heritability for kernel length, kernel breadth, L/B ratio, amylose content, protein content and alkali spreading value were also reported by Krishnaveni and Niveditha (2014).

In the current investigation, the genetic advance as percent of mean was found to be high for the traits linear elongation ratio, breadth-wise elongation ratio and moderate for the traits head rice recovery, kernel breadth, L/B ratio and volume expansion ratio. High heritability coupled with high genetic advance observed for these traits indicates the predominance of additive gene action in the inheritance of these characters and suggests their amenability for effective phenotypic selection in the early generations. Krishnaveni and Niveditha (2014) reported high GA as percent of mean for alkali spreading value and kernel breadth. Combining all superior quality traits in a single line is very difficult. In the present study, different mutant lines were found superior for various quality traits. Among the 83 mutants studied, six mutants *viz.*, 200-84-69-10-11, 200-62-27-25-20, 200-72-6-28-39, 200-71-34-29-46, 250-28-62-27-21 and 250-6-38-29-16 were found to be desirable than the parent ADT (R) 47 for physical grain quality traits and possess slender grains that fall under short, medium and long category. With regard to the cooking traits, the mutant 250-27-69-4-48 is selected as best since it possessed high linear expansion ratio, volume expansion ratio and less breadth-wise expansion ratio than the parent variety. Further, thirty seven mutants were found to possess less breadth-wise expansion ratio of cooked rice than the parent which is a highly desirable trait. Singh (2005) obtained desirable mutants for kernel length, kernel breadth, L/B ratio, gel consistency and alkali digestion value which were significantly superior to the parent Pusa Basmati 1.

Based on the results obtained from this study, mutants were observed to possess good cooking and milling characteristics than the parent. Further selection in advanced generations will lead to isolation of stable mutants with better quality traits than the parent line which can be released as improved varieties.

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