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Stability Analysis for Grain Quality Parameters among the Mutants of ADT(R) 47 Rice (*Oryza sativa*)

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Abstract

Induced mutagenesis was done in the seeds of ADT(R) 47 rice variety with different doses of gamma rays (150 Gy, 200 Gy, 250 Gy and 300 Gy) and EMS (80 mM, 100 mM, 120 mM and 140 mM) at Tamil Nadu Rice Research Institute, Aduthurai during 2012. An experiment was conducted during 2015 at four environments namely, Aduthurai (E_1), Thanjavur (E_2), Tirur (E_3) and Madurai (E_4) to assess the stability of thirteen different grain quality traits among the 16 mutants of the rice variety ADT (R) 47 rice (*Oryza sativa* L.). ANOVA of Eberhart and Russell revealed that, performance of different mutant lines fluctuated significantly from their respective linear path of response to environment. Most of the grain quality parameters showed non-significant mean squares except gel consistency and amylose percentage indicating the influence of genotype×environment (G×E) interactions on these two grain quality measures. The environmental indices for the expression of the traits revealed that Thanjavur is favourable for linear elongation ratio and amylose content. Tirur was favourable for the traits viz., hulling percentage, milling percentage, head rice recovery percentage, kernel length, kernel breadth, kernel length after cooking, breadth after cooking, gel consistency and volume expansion ratio whereas Madurai was favourable for L:B ratio and breadthwise expansion ratio. From the overall assessment, the mutant 200-21-1 was identified to possess desirable head rice recovery percentage and cooking qualities along with stable yield. These mutant was declared stable in expression of trait through Eberhart and Russell model, hence identified as the best mutant for promotion as variety.

Keywords: Rice, *Oryza sativa,* genotype×environment, quality parameters

1. Introduction

Rice has been cultivated in Tamil Nadu in an area of 17.26 lakh ha with an annual production of 7.11 mt with a productivity of 4122 kg ha^{-1} during 2013–14 (Government of Tamil Nadu, policy note, 2015). In Tamil Nadu the major rice growing seasons are *Kuruvai, Thaladi, Samba* and *Navarai*. So far, 155 rice varieties and 5 hybrids have been released for commercial cultivation for the above seasons. Short duration varieties with the duration of 105–115 are found to be ideal for cultivating in Kuruvai and Navarai. The popularly grown short duration varieties in Tamil Nadu are ADT 36, ADT 37, ADT 43, ADT 45, ASD16 and TKM 9. These varieties have an average grain yield of 5.8–6.0 t ha^{-1}. Recently varieties like CO 51, TPS 5 and MDU 6 have been released as region specific varieties. But still there is a demand for new varieties suitable for millers and consumer preferences. The popular rice variety ADT(R) 47 was released for cultivation during the first season in Tamil Nadu. It is 90–100 cm tall with an average of 15–20 productive tillers under normal management conditions. The panicles are compact, 26–28 cm long with approximately 250 grains panicle^{-1} and 1000 grains weigh only 13.5 g. With such a slender grain, it gives an average grain yield of 6.2 t ha^{-1} with potential yield up to 10.6 t ha^{-1} in 125 days. However, this variety is known to possess few undesirable traits viz., just exerted panicle with few ill-filled grains at the base and poor grain threshability. To rectify these drawbacks, ADT(R) 47 was mutagenized using both physical (Gamma ray) and chemical (ethyl methane sulfonate, EMS) mutagens to develop induced mutants that are devoid of these undesirable traits and forwarded to M_5 generation.

2. Materials and Methods

A field experiment was conducted to to induce mutagenesis in the seeds of ADT(R) 47 rice variety with different doses of gamma rays (150 Gy, 200 Gy, 250 Gy and 300 Gy) and EMS (80 mM, 100 mM, 120 mM and 140 mM) at Tamil Nadu Rice Research Institute, Aduthurai during 2012. The desirable 652 mutants identified through selection in M_3 generation were taken for further study during 2014. The nature and magnitude of induced mutants was studied in M_4 generation and the mutants which possessed desirable expressivity for the traits *viz*., earliness, panicle exertion and threshability were shortlisted from the *per se* performance of mutants in M_4 generation. A total of 16 mutants which manifested earliness, moderately well exerted panicle and intermediate panicle threshability in M_4 generation were constituted which served as basic study material for M_5 generation during 2015 (Table 1 and Figure 1). The M_5 generation was grown at multiple locations of Aduthurai (E_1), Thanjavur (E_2), Tirur (E_3) and Madurai(E_4) adopting the same design (Randomised Block Design) and cultural practices. The 16 selected mutant genotypes were grown in a plot size of 1.8 m^2 per family with a spacing of 15×10 cm^2 in randomized block design replicated thrice. Two control genotypes, ADT(R) 47 and ADT 43 were also grown along with the mutants. 13 grain quality traits viz., hulling percentage, milling percentage, head rice recovery percentage, kernel length, kernel breadth, L:B ratio, kernel length after cooking, kernel breadth after cooking, linear elongation ratio, breadthwise elongation ratio, volume expansion ratio, gel consistency and amylose content were estimated in all the studied environments for assessing the stability of genotypes across environments in yield and quality traits. The stability was worked out using Eberhart and Russellmodel by the software TNAUSTAT.

Table 1: List of mutants tested at four different locations in M_5 generation

Sl. No.	Entries	Days to 50% flowering	Panicle exsertion	Threshability
1.	100-16-2	91	7	2
2.	140-35-1	74	7	2
3.	160-39-1	95	7	2
4.	200-21-1	86	7	2
5.	200-26-1	91	7	2
6.	200-30-3	85	7	2
7.	200-49-1	81	7	2
8.	200-55-1	86	7	2
9.	200-69-1	91	7	2
10.	200-70-1	89	7	2
11.	200-72-1	83	7	2
12.	200-81-1	94	7	2
13.	200-146-1	90	7	2
14.	250-29-1	89	7	2
15.	250-34-1	87	7	2
16.	300-54-1	93	7	2

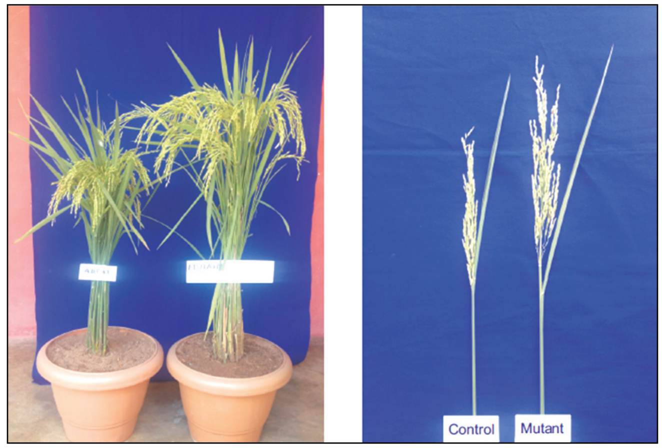

Figure 1: Parent and exerted panicle mutant- M_4 generation

3. Results and Discussion

3.1. *Mean performance of mutants for quality characters over locations*

The mutants viz., 100-16-2, 140-35-1, 160-39-1, 200-21-1, 200-49, 200-55, 200-69-1, 200-70, 200-72-1, 200-81-1 and 200-146-1 exhibited high mean values for the trait HRR when compared to the parent variety ADT(R) 47 (Table 2). Head rice recovery (HRR) varied depending on the variety, grain type, cultural practices and drying condition (Asish et al., 2006). More emphasis should be given to HRR than to total rice yield since it is more important commercially for millers (Jenning et al., 1979). HRR% is a heritable trait although environmental factors and post-harvest handling are known to break the grain during milling (Fan et al., 2000).

The mutants 200-21-1and 200-69-1 had high mean values for linear elongation ratio and low mean values for breadthwise expansion ratio than the parent variety. If rice elongates length wise, it gives finer appearance and it expands girth wise, it gives coarse look. Both the mutants are short in grain size and medium in grain shape. Physical characters i.e., grain shape, size and appearance are very important characters and determine the consumers' acceptability (Subudhi et al., 2012). In this study all the mutants had soft gel consistency (>60 mm) and the mutants viz., 200-21-1, 200-30-3, 200-69-1, 200-72-1 and 200-81-1 possessed intermediate amylose content. The overall analysis showed that the mutant 200-21-1 and 200-69-1 had good cooking quality with acceptable grain shape (Table 3 and 4). These genotypes are also showing stability and superiority for other component characters of grain yield.

3.2. *ANOVA for grain quality parameters across environments*

ANOVA revealed the existence of significant differences among the genotypes for all the 13 grain quality traits (Table

Table 2: Estimates of stability parameters (E&R model) for hulling, milling percentage, head rice recovery and kernel length at different locations

Sl. No.	Mutants/checks	Hulling (%)			Milling (%)			Head rice recovery (%)			Kernel length		
		Mean	b_i	S^2di	Mean	b_i	S^2di	Mean	b_i	S^2di	Mean	b_i	S^2di
1.	100-16-2	75.48	1.96	3.09	68.81	-0.61	0.08	59.43	1.67	0.55	5.28	-1.65	0.00
2.	140-35-1	73.51	1.51	3.44*	68.08	-1.64	5.22**	59.02	0.55	3.79**	5.69	0.66	0.01
3.	160-39-1	78.78	-0.89	2.97	71.74	1.67	7.90**	61.01	1.55	11.57**	5.35	1.47	0.00
4.	200-21-1	76.60	-0.24	-0.23	68.75	-0.57	0.22	58.47	0.38	2.19**	5.44	1.55	0.01
5.	200-26-1	65.50	-0.79	-0.22	61.55	1.91	0.74	52.67	1.59	6.10**	5.39	0.51	0.01
6.	200-30-3	65.26	3.58	-0.12	58.11	2.92	2.97**	50.18	1.28	-0.10	5.46	-1.54	0.01
7.	200-49	72.84	3.32	0.39	67.42	2.16	3.30**	59.82	1.52	5.38**	5.62	1.08	0.00
8.	200-55	72.77	0.37	0.89	66.11	2.95	0.85	60.20	2.16*	0.01	5.54	2.08	0.01
9.	200-69-1	79.95	-0.18	0.18	74.74	-0.87	2.49**	67.37	-1.03	6.56**	5.39	2.45	0.00
10.	200-70	72.82	2.81	1.44	66.27	0.79	3.46**	57.61	1.22	2.86**	5.78	0.50	0.00
11.	200-72-1	74.42	0.92	0.30	68.62	0.88	0.08	59.80	1.55	0.27	5.29	0.63	0.01
12.	200-81-1	78.52	0.25	0.61	69.25	3.74	0.34	60.17	1.95	0.36	5.32	2.37	0.00
13.	200-146-1	75.47	-0.06	-0.35	68.64	-1.51	1.86**	58.61	-0.99	1.04*	5.25	1.94	0.00
14.	250-29-1	71.35	3.49	0.03	63.64	4.60*	0.06	54.04	2.57*	0.05	5.54	1.85	0.01
15.	250-34-1	70.99	0.09	6.13**	62.29	-3.13	-0.08	52.53	-1.86*	0.44	5.57	1.65	0.00
16.	300-54-1	71.83	2.38	-0.13	64.25	4.39	4.41**	54.97	2.77	4.38**	5.71	0.54	0.00
17.	ADT(R) 47	74.56	-0.13	0.91	68.92	-0.04	0.25	57.00	-0.19	1.16**	5.56	1.05	0.00
18.	ADT43	81.45	-0.56	0.29	68.70	0.32	0.06	54.03	1.32	0.52	5.69	0.88	0.00
Mean			74.00			66.99			57.61			5.49	

5). Significant pooled deviation suggested that performance of different mutant genotypes fluctuated significantly from their respective linear path of response to environment.

Most of the parameters showed non-significant mean squares except gel consistency and amylose content indicating the influence of GEI on the two grain quality measures alone. Similar findings of non-significant GE (linear) interaction for kernel length and HRR were obtained by Singh et al. (2013a). The GE (linear) interaction component showed significance for gel consistency and amylose content indicating that the locations had a marked influence on the expression of these parameters among the genotypes which can be predicted in this model. In contrary to that Hissewy et al. (1992) detected significant GEIs for hulling, milling percentage, HRR, linear elongation ratio and amylose content and Nayak et al. (2008) reported significant GEI for grain quality parameters viz., kernel length, L:B ratio, ASV, cooked kernel length, linear elongation ratio, volume expansion and amylose content.

Many workers emphasized that when both linear and nonlinear components were significant, prediction would depend upon relative magnitude of these two measures, whereas the prediction would be more reliable when only linear was significant against nonlinear (Reddy et al., 1998 and Shanmuganathan and Ibrahim, 2005). Predominance of linear component suggested that the performance of the genotypes can be predicted across the environment with great precision. Satyapriyalalitha and Sreedhar (2000) reported nonlinear component of GEI for L:B ratio and volume expansion, while linear component was predominant for amylose content and gel consistency.

The environmental indices for the expression of the traits revealed that Thanjavur is favourable for linear elongation ratio and amylose content. Tirur is favourable for the traits viz., hulling percentage, milling percentage, HRR, kernel length, kernel breadth, kernel length after cooking, breadth after cooking, gel consistency and volume expansion ratio whereas Madurai is favourable for L:B ratio and breadthwise expansion ratio (Table 6).

Out of 13 grain quality parameters taken for study in sixteen mutants, GE linear and environment+(GE) were found to be significant for two characters viz., gel consistency and amylose content. Hence, stability parameters are discussed only for these traits. Among the cooking quality parameters, gel consistency and amylose percentage were influenced by

Table 3: Estimates of stability parameters (E and R model) for kernel breadth, L:B ratio, kernel length after cooking, kernel breadth after cooking at different locations

Sl. No.	Mutants/checks	Kernel breadth			L:B ratio			Kernel length after cooking			Kernel breadth after cooking		
		Mean	b_i	S^2di	Mean	b_i	S^2di	Mean	b_i	S^2di	Mean	b_i	S^2di
1.	100-16-2	1.82	1.15	0.00	2.91	1.76	0.01	6.35	1.43	0.02*	2.26	1.19	0.01
2.	140-35-1	1.90	-0.34	0.01	3.00	-1.02	0.01	6.65	0.94	0.02**	2.43	1.97	0.01
3.	160-39-1	1.89	0.28	0.01	2.84	0.43	0.04*	6.37	1.00	0.02	2.59	1.35	0.00
4.	200-21-1	2.22	-0.60	0.01	2.45	-0.99	0.02*	8.32	1.10	0.00	2.74	0.53	0.00
5.	200-26-1	1.87	2.08	0.00	2.88	3.38*	0.00	7.21	0.87	0.01	2.57	2.34	0.00
6.	200-30-3	2.21	0.30	0.00	2.48	0.10	0.01	7.63	1.33	0.01	2.67	1.96	0.00
7.	200-49	1.84	1.15	0.00	3.05	1.46	0.00	7.43	0.30	0.01	2.28	0.44	0.01*
8.	200-55	1.92	0.61	0.00	2.89	0.09	0.00	6.67	-0.90	0.01	2.35	-0.19	0.01
9.	200-69-1	2.30	0.95	0.00	2.35	0.74	0.00	8.26	0.60	0.01	2.51	-0.22	0.03
10.	200-70	2.17	0.53	0.04	2.68	-0.14	0.05*	6.71	0.20	0.00	2.38	2.44	0.00
11.	200-72-1	2.17	1.12	0.01	2.45	1.43	0.00	7.44	1.04	0.02*	2.56	1.11	0.00
12.	200-81-1	2.32	0.51	0.00	2.30	0.11*	0.00	7.06	2.43	0.00	2.77	-0.72	0.00
13.	200-146-1	1.93	1.58	0.02**	2.72	0.65	0.06**	8.21	0.52	0.00	2.69	-1.75	0.00
14.	250-29-1	2.13	2.86	0.00	2.62	3.67	0.01	6.45	1.46	0.00	2.38	1.95	0.00
15.	250-34-1	2.18	3.32	0.00	2.57	3.59	0.00	6.56	2.75	0.01	2.26	2.26	0.01
16.	300-54-1	2.26	2.19	0.01	2.54	2.45	0.01	7.79	0.61	0.01	2.60	1.10	0.00
17.	ADT(R) 47	2.00	-0.26	0.00	2.79	-0.30	0.01	8.21	1.10	0.00	2.70	0.98	0.01
18.	ADT43	1.92	0.58	0.00	2.97	0.56	0.00	9.27	1.25	0.00	2.67	1.23	0.00
Mean			2.06			2.69			7.37			2.52	

the environments where the mutants were tested. The mean value of mutants for gel consistency ranged from 61.08 mm (200–55) to 96.77 mm (200–70). Seven mutants registered higher mean value for gel consistency than the grand mean of 75.44 mm. The mutant 250-29-1 recorded significant *bi* value and the mutant 200-146-1 showed unit regression. The mutants *viz*., 100-16-2, 140-35-1, 160-39-1, 200-81-1, 250-34-1, and 300-54-1 had significant deviation from regression. Other mutants had non - significant deviation from regression. Amylose percentage among the mutants ranged from 22.78% (200-30-3) to 33.38% (140-35-1). Ten mutants recorded significantly higher amylose percentage than the grand mean of 26.52 per cent. Mutants 200-55 and 200-81-1 had significant negative *bi* values. The mutants *viz*., 100-16-2, 140-35-1, 160-39-1, 200-26-1, 200-70 exhibited *bi* values greater than one. The significant values of $\delta^2 d_i$ were observed in two mutants (140-35-1 and 160-39-1). The remaining mutants recorded non significant deviation from regression where as none of the genotypes recorded zero deviation from regression. The mutant 200-81-1 exhibited near zero values (0.02) for deviation from regression . Gel consistency depends on the variations in amylopectin fractions (Juliano and Perdon, 1975). Addition of nitrogenous fertilizers at heading stage somehow increases the protein content, which subsequently contributes to harder gel consistency (Seetanum and De Datta, 1973). Some high GC rice tends to give hard cooked rice and rice products due to the presence of large amylopectin molecules (Perez et al., 1979). Amylose content is the major factor for eating quality (Juliano and villareal, 1993). It determines the hardness or stickiness of cooked rice, cohesiveness, tenderness, colour of cooked rice. Higher amylase content (>25.0%) gives non-sticky soft or hard cooked rice. Rice varieties having 20–25% amylase content gives soft and flaky cooked rice. It is an indicator of volume expansion and water absorption during cooking (Deyner et al., 2001). Amylose content, starch, gel consistency and non-reducing sugar content decrease with elevated temperature (Pandey et al., 2007). Two mutants viz., 200-21-1 and 200-146-1 were found to be stable over locations with favourable mean, around unit regression and least deviation from regression for gel consistency. Whereas 200-21-1 and 200-72-1 were found to be stable over locations for amylose percentage **(**Table 2**)**

Table 4: Estimates of stability parameters (E and R model) for linear elongation ratio, breadth wise elongation ratio, gel consistency and amylose content at different locations

Sl. No.	Mutants/ checks	Linear elongation ratio			Breadth wise elongation ratio			Volume expansion ratio			Gel consistency			Amylose (%)		
		Mean	b_i	S_2di	Mean	b_i	S_2di	Mean	b_i	S_2di	Mean	b_i	S_2di	Mean	b_i	S_2di
1.	100-16-2	1.21	-4.08	0.01**	1.24	2.17	0.00	3.34	2.06	0.00	71.38	7.93	2.04*	26.70	1.82	0.36
2.	140-35-1	1.17	4.35*	0.00	1.28	-2.18	0.00	3.42	0.63	0.00	72.62	2.04	3.54**	33.38	5.12	2.36**
3.	160-39-1	1.19	-3.36	0.00	1.37	2.37	0.01*	3.96	0.71	0.01	63.21	-1.07	5.06**	28.99	4.80	1.19*
4.	200-21-1	1.54	0.21	0.00	1.23	0.26	0.00	4.41	0.75	0.00	61.55	0.97*	0.05	23.64	0.93*	0.20
5.	200-26-1	1.34	-2.81	0.00	1.37	2.62	0.00	3.28	2.39	0.01	84.80	3.34	0.67	28.55	3.99	0.89
6.	200-30-3	1.40	0.17	0.01*	1.21	0.08*	0.00	3.95	0.27	0.02*	93.93	-2.54	0.73	22.78	-1.22	0.03
7.	200-49	1.32	-2.03	0.00	1.24	3.00*	0.00	3.82	0.32	0.03**	72.00	2.88	0.47	26.76	-0.26	0.08
8.	200-55	1.21	-5.47	0.00	1.23	2.35	0.00	3.68	0.72	0.01	61.08	2.87	0.27	27.74	-0.37	-0.10
9.	200-69-1	1.53	3.47	0.00	1.09	-1.12	0.00	4.36	1.73	0.01	79.71	-5.21	1.52	23.30	-0.68	0.53
10.	200-70	1.16	1.25	0.00	1.10	-0.55	0.00	3.56	1.43	0.07**	96.77	4.29	0.85	27.52	1.40	-0.01
11.	200-72-1	1.41	7.60	0.00	1.18	0.62	0.00	4.36	0.83	0.01	74.30	-1.24	0.99	24.39	0.82*	-0.10
12.	200-81-1	1.33	6.29*	0.00	1.20	-0.04	0.00	4.19	3.47	0.03**	95.93	1.60	3.33**	23.38	-2.21	0.02
13.	200-146-1	1.57	-1.50	0.00	1.40	0.58	0.03**	4.19	1.75	0.00	62.63	1.00*	-0.05	30.14	0.65	0.64
14.	250-29-1	1.17	5.61*	0.00	1.12	2.47	0.00	3.64	-0.66	0.00	89.77	8.12**	-0.11	31.23	-0.26	0.67
15.	250-34-1	1.18	5.18	0.00	1.04	2.02	0.00	3.93	0.02	0.01	96.20	0.09	4.63**	28.03	0.85	-0.04
16.	300-54-1	1.37	-1.40	0.00	1.16	3.08	0.00	4.28	1.12	0.01	68.28	-3.08	2.69**	26.43	-0.07	-0.01
17.	ADT(R) 47	1.48	2.41	0.00	1.35	-0.58	0.00	4.27	-1.30*	0.00	57.34	-2.10	-0.03	24.30	0.24	-0.08
18.	ADT43	1.63	2.02	0.00	1.39	0.85	0.00	4.19	1.76	0.00	56.38	0.70	0.31	20.10	3.20	0.53
Mean			1.35			1.23			3.94			75.44			26.52	

Table 5: ANOVA for stability of rice mutants and checks for different grain quality characters (E and R model)

Source	df	Mean sum of squares												
		H	M	HRR	KL	KB	L/B ratio	KLAC	KBAC	LER	BER	VER	GC	AC
G	17	75.24**	60.70**	64.73**	0.106**	0.155**	0.290**	2.842**	0.117**	0.097**	0.063**	0.983**	812.13**	44.86**
E+ (G×E)	54	1.43	2.57	3.54	0.009	0.014	0.025	0.016	0.007	0.001	0.006	0.016	2.55*	0.78*
E (L)	1	7.49*	11.65**	36.41**	0.129**	0.212**	0.239**	0.297**	0.055**	0.001	0.061**	0.133**	5.89	4.78**
G×E (L)	17	0.99	3.15	3.33	0.009	0.013	0.028	0.017	0.004	0.001	0.008	0.009	4.17**	1.11**
PD	36	1.47**	2.04**	2.73**	0.006**	0.009**	0.017**	0.010**	0.007**	0.0008**	0.004**	0.016**	1.70**	0.51**
Pooled error	136	1.15	0.42	0.34	0.007	0.005	0.013	0.006	0.005	0.0006	0.003	0.006	0.60	0.34

G: Genotypes; E: Environment; L: Linear; PD: Pooled deviation (Non-linear); H: Hulling; M: Milling; HRR: Head rice recovery; KL: Kernel length; KB: Kernel breadth; KLAC: Kernel length after cooking; KBAC: Kernel breadth after cooking; LER: Linear elongation ratio; BER: Breadthwise expansion ratio; VER: Volume expansion ratio; GC: Gel consistency; AC: Amylose content; *: Significant at (p=0.05); **: Significant at (p=0.01)

Table 6: Environmental indices (Ij) for different grain quality characters in rice mutants and checks in four environments

Sl. No.	Characters	Aduthurai	Thanjavur	Tirur	Madurai
1.	Hulling percentage	-0.37	0.01	0.50	-0.14
2.	Milling percentage	0.15	-0.32	0.59	-0.42
3.	Head rice recovery percentage	0.35	-0.61	0.99	-0.74
4.	Kernel length	-0.06	0.00	0.06	-0.01
5.	Kernel breadth	-0.03	0.00	0.09	-0.06
6.	Kernel L:B ratio	0.01	-0.01	-0.08	0.08
7.	Kernel length after cooking	-0.06	0.02	0.10	-0.05
8.	Kernel breadth after cooking	-0.02	-0.03	0.04	0.01
9.	Linear elongation ratio	0.003	0.00	0.00	-0.01
10.	Breadth wise expansion ratio	0.01	-0.02	-0.03	0.04
11.	Gel consistency	-0.30	-0.04	0.47	-0.14
12.	Amylose content	0.13	0.21	-0.44	0.10
13.	Volume expansion ratio	0.00	-0.02	0.07	-0.05

4. Conclusion

Two mutants viz., 200-21-1 and 200-146-1 were found to be stable over locations for gel consistency. Whereas, 200-21-1 and 200-72-1 were found to be stable over locations for amylose content. From the overall assessment, the mutant 200-21-1 was identified to possess have desirable head rice recovery percentage and cooking qualities along with stable yield. These mutant was declared stable in expression of trait through Eberhart & Russell model, hence identified as the best mutant for promotion as variety.

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