RESEARCH PAPER

Grain Dimensions And Cooking Quality Of Samba Mahsuri (Rice) EMS Mutants

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Abstract
Rice is an important food crop. The demand for rice quality has been raised, mainly include processing quality, appearance quality, cooking and taste quality, nutritional quality, and aroma (Basmati and aromatic short grain rice). Samba Mahsuri (SM) is a popular mega variety of Southern part of India with good cooking quality. Hence, in this study, grain quality and cooking properties were assessed in 89 promising Ethyl methyl sulphonate (EMS) SM mutants along with wild type were selected (based on yield and morphological data) and screened for grain quality and cooking parameters by standard protocols and compared with wild type SM.

Among the Samba Mahsuri and mutants (90) examined for kernel length (KL) and results were ranged from 3.6 to 6.8 mm, kernel breadth (KB) ranged from 1.4 to 2.367 mm, kernel length after cooking (KLAC) ranged from 5.8 to 10.97 mm, kernel breadth after cooking (KBAC) ranged from 2.07 to 3.20 mm, KL/KB ratio before cooking ranged from 2.04 to 3.98, KLAC/KBAC ratio after cooking ranged from 2.35 to 4.84 and elongation ratio (ER) ranged from 1.280 to 1.820. The KL and KLAC were highest in mutant Ti-13 and least in Ti-60. The KLAC/KBAC ratio highest for Ti-15. Highest ER was shown by Ti-38. Although the wild SM grain type was medium slender, SM mutants recorded diverse grain types- short bold, short slender, medium slender, medium bold, long slender and long bold. Amylose content was very low in 14, low in 37, intermediate in 20 and high in 19 mutants. Gelatinization temperature was high in 57, medium in 15 and low in 18. Gel consistency was hard in 52, medium in 24 and soft in 14 mutants. In multiple correlation analysis, KL showed significant positive association with KB, KBAC, KLAC, KL/KB and KLAC/KBAC. While KL noted significant negative association with ER. ASV noted significant negative correlation with amylose content. Among all mutants 19 mutants are showing similar Amylose Content, 56 mutants are noted similar Gelatinization temperature(high) and 23 mutants noted similar Gel Consistency (soft) to Wild type i.e. Samba Mahsuri .

Keywords: Ethyl methyl sulphonate, kernel length, kernel breadth, elongation ratio, L/B ratio, gel consistency

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INTRODUCTION

Rice is one of the most important food crops, staple food for more than half of the world's population (65%) and fulfills over 21% of total dietary requirements (Sharma.N,2019) which contributes the nutritional status of entire population.(Sinthuja.R et.al.,2021). More than 90% of the world's rice is cultivated and consumed in Asia (Khush.G.S,2005). Grain quality is a general concept which covers many characteristics ranging from physical to biochemical and physiological properties. (Chen et.al, 2012) and also awareness of consumers on grain quality(Thissa Marasingha et.al,2024).India is the world's first largest producer of rice. The type of rice grown in different parts of India depends on the weather, soil, structure, characteristics and purposes. Rice quality is a complex trait influenced several factors and especially eating quality,appearance and nutritional value are the major demands of consumers influencing the market pricing (Sharmin Sultana et.al,2022).The three major components of rice Starch (75%), protein (4.3-20.2%;Chattopadhyay et al.; Santos et al. 2013), and lipids(2.4-3.9% ; Juliano ,1977) are closely related to its eating quality (Guo et al., 2023). Rice (*Oryza sativa* L.) 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). Quality desired in rice vary from one geographical region to another and consumers preferences are also different in accepting and consumption.).The physicochemical characteristics include kernel length, kernel breadth, L/B ratio, grain size and shape (Rita and Sarawagi,2008); and cooking quality include alkali digestion value, gelatinization temperature and elongation ratio are some important for deciding the quality. Kernel size, shape and L/B ratio are important features for grain quality assessment.. Aroma, hardness and roughness are depends up on temperature and variety specific which affects the sensory properties. Good quality and healthy seed is a basic and critical input for the sustained agriculture production. Successful agriculture depends on the quality of seeds used for sowing. (G.Kumar et.al,2017).Alkali digestion value and gelatinization temperature are major rice traits, which are directly related to cooking and eating quality. Gelatinization temperature is reasonably high in heritability. In the present study we have evaluated the grain quality characteristics (physical and cooking)

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to set up criteria for rice grading for improvement of pricing as well as selection of rice varieties.

Samba Mahsuri (BPT-5204) is a mega variety of India released in 1984. It is highly popular in Southern and Eastern parts of India. It holds highest acreage in the states of Andhra Pradesh, Telangana, Tamilnadu and Karnataka. It shows excellent cooking quality with good yield and desirable (low) Glycemic Index. Hence, it is favoured by consumers and farmers in India. However it is susceptible to biotic stresses like sheath blight, blast, bacterial leaf blight and insect pests such as yellow stem borer ,brown plant hopper and gall midge.

Samba Mahsuri is an ideal genotype to develop a comprehensive mutant population due to its excellent combining ability. Mutant resources can be used to create variations and novel gene identification of specific traits and deciphering gene function. The mutants can be used as donors in rice improvement programs. Samba Mahsuri mutants (around 10000) were developed by IIRR and CCMB jointly using Ethyl methane sulphonate as mutagen (Potupureddy Gopi et.al,2021). Further, they were evaluated in field for three seasons and 89 promising mutants having better yield and tolerance to various diseases were identified. As grain quality is also important, in this study, the selected 89 promising EMS Samba Mahsuri mutants were screened for standard physical and biochemical grain quality parameters along with the wild type Samba Mahsuri.

MATERIALS AND METHODS

The promising ninety (89+1) samba Mahsuri mutants were cultivated and multiplied in IIRR, Rajendranagar, Hyderabad field following standard package of practices (every year & every season).The grain quality and cooking properties were estimated in IIRR, Physiology laboratory by following standard protocols during 2022-2023.

The seeds were sown on nursery beds and 25 days old seedlings were transplanted as single seedling per hill in the field a uniform spacing of 20 cm between rows and 15 cm between plants. A layer of 2–3 cm water was maintained constantly till the establishment of seedlings. Thereafter about 5 cm of water was maintained upto dough stage of the crop. The farm soil is alkaline vertisol, with a pH of 7.94. The recommended dose of fertilizers 100 kg ha^{-1} of Nitrogen in three split doses with one fourth as basal dose, one half at the time of initial tillering stage and one fourth at active tillering stage, entire dose of 40 kg ha^{-1} of phosphorus and 60 kg ha^{-1} of Muriate of Potash (MOP) per hectare were applied at the time of transplanting as basal dose. Required weed management and plant protection measures were timely undertaken for healthy crop production. The seed was collected ,stored for 3months and seed was dried properly and dehusked, polished and cleaned thoroughly. The moisture is maintained at 14 and used for screening .

Data was recorded in three replications to assess the grain quality and cooking properties of rice. Data pertaining to different parameters *viz.* kernel length, kernel breadth, kernel length after cooking, kernel breadth after cooking, L/B ratio before and after cooking, size and shape of grain were recorded on ten randomly selected grains of each replication. Kernel length and width of ten dehusked , polished and cleaned thoroughly rice grains of each replication was measured by Vernier calipers.(Rice grain quality analysis ; Aravind et.al, 2021 ; ICAR-IIRR) .Based on average kernel length and L/B ratio before cooking, size and shape of grains were categorised (Table-A)

Preferences for grain size and shape vary from one group of consumers to another. Some ethnic groups prefer short bold grains, some have a preference for medium long grains, and long slender grains. In general, long grains are preferred in the Indian subcontinent, but in Southeast Asia the demand for medium to medium long is preferred. In temperate areas, short grain varieties are prevalent. There is a strong demand for long-grain rice in the international market.

Basing on grain length and L/B ratio, rice genotypes were classified into seven grain types as per Govindaswamy (1985) with minor modification as mentioned below (Table A).

Table A : Classification of rice genotypes based on grain type

Grain type	**Grain dimensions in mm**
Long slender (LS)	Length ≥ 6.0 & Length/ Breadth ratio ≥ 3.0
Short slender (SS)	Length < 6.0 & Length/ Breadth ratio ≥ 3.0
Medium slender (MS)	Length < 6.0 & Length/ Breadth ratio 2.5 to 3.0
Long bold (LB)	Length ≥ 6.0 & Length/ Breadth ratio < 3.0
Medium bold(MB)	Length 6.0 -7.0& Length/ Breadth ratio 2.0 to 2.5
Short bold (SB)	Length < 6.0 & Length/ Breadth ratio < 2.5
Extra long slender(ELS)	Length ≥ 9.0& Length/ Breadth ratio ≥ 4.0

Estimation of Amylose: Amylose content was determined by Juliano method (1971) . Simplified procedure of Juliano et al., (1981) with minor modification was used for the estimation of amylose content. A powdered milled rice of 100 mg was weighted and taken into 100 ml volumetric flask. It was added with 1 ml 95% ethanol and 9 ml 1 N NaOH and left overnight. On the Subsequent day distilled water was added to the samples to make up the final volume to 100 ml. Mixed solution of 5 ml from 100 ml was pipetted out into another 100 ml volumetric flask. 1 N acetic acid (1ml) followed by 2 ml iodide solution were added and the volume was made upto to 100 ml. The content was stirred and allowed to stand for 20 min before absorbance was measured at 620 nm with a UV-Spectrophotometer. Amylose concentration was obtained by plotting the absorbance in the potato amylose standard curve. Amylose content of each genotype was expressed as percentage to total quantity of sample taken for analysis.

Alkali digestion value: An estimate of the gelatinization temperature is indexed by the alkali digestibility test (Little *et al.,* 1958). The spread of the 6 milled rice kernels in 1.7 % KOH solution for a period of 23 hours was rated as per Standard Evaluation System for Rice (IRRI, 1996). Six milled kernels were placed in 10 ml of 1.7 % KOH solution in Petri dish and arranged in a manner so that they do not touch each other and were allowed to stand for 23 hours at 30 ^{0}C to score spreading on 1-7 scale (Table 4).

Gel consistency : A standard protocol to determine the gel consistency was given by Cagampang et.al.,1973. 100 mg of rice flour was taken in triplicates in test tubes. 0.2 ml of thymol blue reagent was added, gently mixed for a while and 2.0 ml of 0.2 N KOH solution was added and the contents were mixed in a vortex.The test tubes were kept in a waterbath for 8 minutes at 90-100^{o}C and each tube was covered with glass marble ;then tubes were cooled for 5 minutes and the contents were mixed in a vortex. Then the test tubes were kept in ice bath (0-2^{o}C) for 20 minutes.Then the test tubes were allow laid horizontally for one hour over a sheet of graph paper.Length of the blue coloured gel was measured from the inside bottom of the test tube to get the gel front as gel consistency of the sample. The length of the gel of each sample were recorded and scored.

Results& Discussion

Grain dimensions before and after cooking among the mutants ANOVA indicates that variation was highly positively significant for KL at P 0.001 , KB at P 0.001 , KLAC at P 0.001 and KBAC at P 0.001 among Samba Mahsuri mutants **(Table-1).** kernel length (KL) ranged from 3.6 to 6.8 mm, kernel breadth (KB) from 1.4 to 2.367 mm, kernel length after cooking (KLAC) from 5.8 to 10.97 mm, kernel breadth after cooking (KBAC) from 2.07 to 3.20 mm, L/B ratio before cooking from 2.04 to 3.98, L/B ratio after cooking (L/B AC) from 2.35 to 4.84 and elongation ratio (ER) from 1.280 to 1.806. The mutant Ti-13 showed highest kernel length before and after cooking and Ti-60 showed lowest ; L/B ratio after cooking is highest for Ti-15 which also recorded lowest kernel breadth after cooking; while highest elongation ratio shown by Ti-38;BB-32P1 recorded high elongation ratio with lowest kernel breadth before cooking and kernel elongation is also influenced both by genetic factors and temperature.

KL showed positive significant association with KB, KBAC, KLAC and L/B ratio and L/B (AC) while negative with ER. The positive significant association was also found between KB and KBAC,KLAC,and negative significant association with L/B ratios and ER ; L/B ratio has positive significant association with L/B (AC) and negative one with KBAC ,ER; KLAC noted positive correlation with KBAC, L/B (AC) , and KBAC has shown negative correlation with L/B (AC); L/B (AC) has shown significant positive correlation with ER. **(Fig-2).**

Cooking quality can be affected by both genetic and environmental factors. It has been reported that some stress conditions may alter the biochemical composition and nutritional properties (Sulthan Rifasa et.al, 2025).

Some rice varieties expand more in size than others upon cooking. Generally, the rice kernels absorb water to increase volume, increase length or breadth. The kernel breadth increase is not desirable, but, lengthwise expansion without increase in girth is considered a highly desirable trait in some high quality premium rice. The kernel elongates upon hydration and starch gelatinization occurs without increase in girth is considered as desirable cooking quality trait. Hence, the rice with higher elongation ratio is more preferable (A.K. Singh et.al, 2012). The elongation of rice grains during cooking is influenced by both the rice variety and milling degree (Mohapatra D. et.al, 2006). Notably, elongation ratio rather than L/B ratio is better quality index (Shahidullah et.al,2009).Four rice genotypes were evaluated for grain yield, quality and nutrient content revealed that enhancement of micro nutrients in rice is possible with high yield and good cooking quality.(Madhubabu et.al,2017).In 2019 a study was done on Morphometric,Physico-chemical and Micronutrient Characterization of Rice in 51accessions. Landraces of Sikkim Himalayas and recorded amylose content range from14.9 to 25.87%,low GT (high ASV) and soft gel consistency mostly. A study was done in 2019 on 190 rice genotypes for characterization of grain nutritional and physico-chemical quality in landraces lead to ultimate identification of promising donors for biofortification and grain quality improvement in rice.(Haritha Bollinedi et.al,2020) The grain type based on shape and size (appearance quality)can influence the market value and preferences of consumers for acceptance. The grain type among mutants showed various forms **(Fig-1)** : 13 are long slender, 48 are medium slender (including wild type), 18 are short slender, 2 are long bold, and 9 are short bold.

Cooking quality parameters of SM mutants:

ANOVA indicates that the variation among Samba Mahsuri mutants (89+1) was highly significant for AMY at P 0.001, GC at P 0.001 and ASV at P 0.001 **(Table-1).** AMY content ranged from 5.16 to 43.33%.

Of these mutants, 14 were very low, 37 were low, 20 were intermediate and 19 were high. None of these mutants noted waxy category of amylose content.

Amylose content is considered as a crucial indicator of rice grain quality. Rice genotypes were classified into waxy (1-2), very low (2-9), low (9-20), intermediate (20-25) and high (25-33) based on amylose content in the milled rice using 610 nm and potato amylose as standard (Juliano, 1971, Rao et.al,2016). Grain quality plays major role in consumer acceptance which is region specific and generally sticky rice contains low amylose while well separated rice contains intermediate amylose content (20-25%). Amylose content directly correlates with cohesiveness, tenderness, color and glossiness of cooked rice (Rohilla.R et.al,2000).

The rice starches with high amylose amylopectin ratio take up more water during boiling and are considered to be more desirable for cooking purpose. Amylose content affects the cooking and eating properties and difference in rice varieties such as grain whiteness, grain shape. The high amylose content (AC) is correlated to the high volume expansion ratio and flakiness of rice. High AC in rice grain causes rice to become dried, decrease in softness and hard upon cooling in contrast to low amylose content. Amylose content varies with environmental conditions, especially the raise in temperature causes decrease in amylose content during ripening stages (Cruz et.al, 2000).ASV has shown significant negative correlation with amylose content (J-Juliano method) among the SM mutants (**Fig-3).**The ASV values ranged from 1 to 7 among the SM mutants (90).

ASV is negatively correlated with Gelatinization temperature (GT). Rice varieties were classified as low (55°C to 69°C), intermediate (70°C to 74°C), and high (>74°C) based on ASV. Of the 90 SM mutants, 57 were high, 15 were medium and 18 were low.

The alkali test is performed on whole-grain milled rice, whereas GT is done on the starch granules. Rice grain having intermediate GT are highly desirable (Bansal et al., 2006 and Bhonsle, 2010). GT is a physical property of the rice starch and refers to the range of temperature within which starch granules start swelling irreversibly in hot water with loss of crystallinity and birefringence. In other words, GT determines the time taken to cook the rice. The variation in cooking times among these varieties likely correlates with their GT's (Bhattacharya et.al., 1972). The quality and quantity of starch in rice endosperm together with GT strongly influence the cooking quality of rice (Ghosh and Govindswamy, 1997) such as water uptake, volume expansion and linear kernel elongation (Tomar and Nanda, 1985). If water absorption into the kernels is insufficient, the kernel may not become fully gelatinized during cooking, resulting in hard texture (Seki and Kainuma, 1982). The storage time has an effect on rice pasting as well as cooking and eating characteristics which are greatly affected by GT and AMY (Bhonsle et.al, 2010). ASV ranged from 4.0 to 7.0 in 24 genotypes (Suman et al., 2020), 2 to 7 in 192 genotypes (Parikh et al., 2023). Rice varieties were categorized into hard GC (26 mm to 40 mm), medium GC (41 mm-60 mm) and soft GC (61 mm-100 mm). Of the 90 SM mutants, soft gel consistency (14), medium gel consistency (24), hard gel consistency (52). Gel consistency is a good index of cooked rice texture. Varieties having same amylose content may differ in tenderness and therefore, the cooked rice may be differentiated by the gel consistency test (Cagampang *et al.,* 1973). Within the same amylose group, varieties with softer gel consistency are generally preferred by the consumers, For e.g. IR5 and IR8 had similar amylose content, but IR5 always scored higher than IR8 for acceptability in panel test because IR5 had soft gel consistency (Niharika et.al,2019). Studies showed that two rice cultivars with the same amylose content may be differentiated with gel consistency test and they have various cooking qualities. However, rice with soft GC cooked slowly and stayed soft even after cooling; thus, consumers prefer rice having soft GC. The competitiveness of local rice varieties need to be improved in quality by adopting a marketing strategies that emphasizes the nutritional quality and suitability for consumption.The organoleptic test was conducted for the appearance, cohesiveness, tenderness on touching and chewing, taste, aroma and overall acceptability of cooked rice and evaluated by trained assessors using the above descriptive analysis in a control panels. It is also emphasized that the training and recruiting the sensory expert panel are important in the process of sensory analysis and organoleptic test (Lefebvre et al., 2010).

The results obtained for grain dimensions and grain quality of Samba Mahsuri mutants are tabulated based on grain type as Long slender (**Table-2**),Medium slender **(Table-3),**Short slender (**Table-4)** and Long bold(**Table-5)** and Short bold(**Table-6**).The variation in grain types can be seen in **Fig-1**.

Table -1: ANOVA of grain dimensions and cooking quality parameters of SM mutants.

Parameter		Df	Sum Sq	Mean Sq	Fvalue	Pr(>F)
KL	Genotype	89	121.64	1.3668	50.41	<2e-16***
	Residuals	180	4.88	0.0271		
KB	Genotype	89	11.08	0.12451	11.44	<2e-16***
	Residuals	180	1.96	0.01089		

KLAC	Genotype	89	210.34	2.3634	28.4	<2e-16***
	Residuals	180	14.98	0.0832		
KBAC	Genotype	89	15.984	0.1796	11.74	<2e-16***
	Residuals	180	2.753	0.0153		
AMYJ	Genotype	89	13630	153.15	15.55	<2e-16***
	Residuals	90	886	9.85		
GC	Genotype	89	30114	338.4	57.19	<2e-16***
	Residuals	90	533	5.9		
ASV	Genotype	89	746.3	8.386	1.295e+29	<2e-16***
	Residuals	90	0.0	0.000		

Table-2: Grain dimensions and quality parameters of SM mutants with Long Slender grain type

S.No	Entry	KL	KB	KLAC	KBAC	L/B	L/B (AC)	ER	AC	GC	ASV
1	Ti-7	6.63±0.12	1.67±0.06	10.17±0.21	2.63±0.06	**3.98**	3.86	1.53	35.25±1.14	31±1.41	7
2	Ti-11	6.23±0.25	2.03±0.15	9.43±0.57	2.63 ±0.12	3.08	3.59	1.51	11.78±3.20	57.5±3.54	5
3	Ti-12	6.43±0.15	2.07±0.12	9.37±0.29	2.47 ±0.12	3.12	3.80	1.46	6.87±0.14	30±0.00	2
4	Ti-13	**6.80±0.52**	1.73±0.12	**10.97±0.65**	2.30±0.10	3.95	4.78	1.62	20.92±1.38	42.5±3.54	7
5	Ti-14	6.13±0.15	2.03±0.06	9.67±0.15	2.50 ±0.00	3.02	3.87	1.58	21.37±4.94	30±0.00	5
6	Ti-15	6.60±0.26	1.73±0.06	10.00±0.20	2.07±0.06	3.81	**4.84**	1.52	14.64±2.19	27.5±3.54	6
7	Ti-27	6.13±0.32	1.97±0.06	9.30±0.36	2.50 ±0.10	3.12	3.72	1.52	22.81±4.18	50±0.00	1
8	Ti-40	6.10±0.26	1.97±0.06	8.10±0.00	2.43±0.06	3.10	3.33	1.33	18.08±0.39	25±0.00	2
9	Ti-43	6.57±0.06	1.80±0.10	9.93±0.15	2.37 ±0.12	3.66	4.20	1.51	7.80±0.05	35±0.00	6
10	Ti-44	6.03±0.15	1.80±0.10	8.60±0.26	2.70±0.10	3.36	3.19	1.43	18.75±1.10	35±0.00	5
11	Ti-45	6.30±0.10	2.07±0.06	8.07±0.61	2.67 ±0.15	3.05	3.04	1.28	24.74±0.21	57.5±3.54	2
12	SB-22	6.00±0.26	1.70±0.10	9.50±0.62	2.73 ±0.23	3.54	3.48	1.59	12.24±1.01	25 ±0.00	2
13	SB-170	6.70±0.17	2.00±0.00	9.10±0.10	3.03±0.06	3.35	3.00	1.36	10.38±0.48	52.5±3.54	2

Table-3: Grain dimensions and quality parameters of SM-mutants with Medium Slender grain type

S.No	Entry	KL	KB	KLAC	KBAC	L/B	L/B (AC)	ER	AC	GC	ASV
1	Ti-5	5.60±0.10	2.17±0.06	9.20±0.36	2.93±0.06	2.59	3.14	1.64	9.76±0.21	57.5±3.54	7
2	Ti-6	4.93±0.06	1.97±0.06	7.57±0.35	2.40 ±0.30	2.51	3.20	1.53	21.70±1.62	30 ±0.00	3
3	Ti-9	4.87±0.06	1.93±0.06	7.87±0.06	2.63±0.32	2.52	3.02	1.62	21.96±0.97	52.5±3.54	3
4	Ti-10	5.27±0.06	1.93±0.12	7.63±0.32	2.80 ±0.10	2.73	2.73	1.45	18.97±0.64	30±0.00	3
5	Ti-16	5.63±0.15	2.17±0.06	7.97±0.21	2.70 ±0.10	2.6	2.95	1.42	5.49±0.68	32.5±3.54	7
6	Ti-18	5.30±0.10	1.80±0.10	7.77±0.31	2.27 ±0.15	2.95	3.44	1.47	9.24±4.54	55±0.00	1
7	Ti-25	5.43±0.25	1.90±0.10	9.40±0.17	2.47±0.06	2.87	3.81	1.73	9.07±1.60	30±0.00	1
8	Ti-26	5.97±0.06	2.10±0.00	8.93±0.38	2.53±0.06	2.84	3.53	1.50	9.76±2.19	42.5±3.54	2
9	Ti-28	4.83±0.06	1.90±0.00	7.80±0.26	2.50 ±0.20	2.54	3.13	1.61	19.30±2.28	30 ±0.00	1
10	Ti-29	5.80±0.56	2.03±0.06	9.27±0.23	2.50 ±0.20	2.85	3.72	1.61	11.88±0.74	50±0.00	2
11	Ti-35	4.80±0.10	1.63±0.12	7.90±0.36	2.40±0.10	2.95	3.29	1.65	20.48±5.84	25±0.00	1
12	Ti-36	5.07±0.12	1.80±0.00	8.07±0.12	2.43 ±0.12	2.81	3.32	1.59	6.99±0.89	27.5±3.54	2
13	Ti-37	4.93±0.32	1.90±0.10	7.30±0.26	2.67±0.06	2.60	2.74	1.48	12.62±0.56	25±0.00	2
14	Ti-38	4.83±0.06	1.73±0.06	8.80±0.36	2.60±0.10	2.79	3.38	**1.82**	25.90±3.69	57.5±3.54	3
15	Ti-41	5.83±0.12	2.10±0.00	7.90±0.30	2.60 ±0.17	2.78	3.05	1.35	8.81±3.82	20±0.00	2
16	Ti-47	5.40±0.10	2.13±0.12	8.37±0.06	2.87±0.06	2.54	2.92	1.55	14.51±4.50	60±0.00	4
17	Ti-48	5.97±0.06	2.07±0.06	9.00±0.26	2.93 ±0.12	2.89	3.07	1.51	8.25±0.02	25.5±0.71	2
18	Ti-50	5.10±0.10	1.80±0.10	8.10±0.17	2.87±0.12	2.84	2.83	1.59	9.23±1.06	26.5±2.12	2
19	Ti-55	5.20±0.17	1.93±0.12	8.23±0.38	2.90 ±0.17	2.70	2.84	1.59	8.58±0.20	27.5±3.54	7
20	Ti-57	4.83±0.15	1.93±0.06	7.57±0.35	2.93±0.06	2.50	2.58	1.57	31.19±0.49	25±0.00	1
21	Ti-114	5.13±0.21	1.87±0.12	8.27±0.21	2.60 ±0.10	2.76	3.18	1.61	9.40±2.65	60±0.00	2
22	Ti-125	4.97±0.25	1.73±0.12	7.93±0.06	2.33±0.12	2.88	3.41	1.60	23.90±0.93	30±0.00	1

23	Ti-128	4.50±0.10	1.63±0.06	7.53±0.35	2.30 ±0.26	2.76	3.32	1.68	23.99±1.07	25±0.00	1
24	Ti-132	4.33±0.06	1.63±0.06	7.33±0.15	2.40 ±0.10	2.66	3.06	1.69	21.52±2.19	25.5±0.71	1
25	Ti-139	5.57±0.25	2.00±0.10	9.80±0.00	2.93±0.06	2.79	3.34	1.76	9.10±1.48	25.5±0.71	2
26	Ti-170A	4.50±0.10	1.70±0.10	7.73±0.35	2.60 ±0.17	2.65	2.98	1.72	10.91±0.82	60 ±0.00	2
27	93R	4.43±0.12	1.60±0.10	7.67±0.15	2.47±0.06	2.99	2.92	1.70	12.05±1.14	60±0.00	1
28	**SM**	**4.17±0.12**	**1.40±0.10**	**7.10±0.36**	**2.43±0.12**	**2.78**	**3.11**	**1.73**	**24.01±2.76**	**42.5±3.54**	**1**
29	SB-20	5.33±0.15	2.00±0.00	9.07±0.06	**3.20±0.00**	2.67	2.83	1.70	9.49±0.07	60 ±0.00	6
30	SB-23	4.67±0.15	1.70±0.10	7.80±0.26	2.27±0.06	2.75	3.44	1.67	13.23±0.55	35.5±0.71	2
31	SB-52	4.93±0.12	1.67±0.12	7.67±0.12	2.30 ±0.10	2.97	3.34	1.56	12.93±2.25	26.5±2.12	2
32	SB-62	5.00±0.10	2.00±0.10	7.90±0.10	2.80±0.00	2.50	2.82	1.58	10.83±1.12	45 ±0.00	6
33	SB-87	5.00±0.10	1.83±0.06	8.07±0.15	2.37±0.06	2.73	3.41	1.61	21.13±3.70	20 ±0.00	2
34	SM-48	5.13±0.06	2.00±0.00	7.97±0.21	2.47 ±0.12	2.57	3.23	1.55	24.54±9.77	55±0.00	1
35	SM-92	5.17±0.21	1.97±0.12	8.23±0.31	2.63 ±0.15	2.63	3.14	1.59	10.59±1.91	35.5±0.71	1
36	BB-32p2	4.97±0.06	1.83±0.06	7.53±0.29	2.53±0.06	2.71	2.98	1.52	26.66±7.96	35±0.00	1
37	BB-36p2	4.60±0.10	1.63±0.06	7.47±0.21	2.53 ±0.15	2.82	2.95	1.62	19.86±0.24	36.5±2.12	1
38	BB-36p3	4.60±0.10	1.63±0.06	7.53±0.15	2.37 ±0.12	2.82	3.19	1.64	29.67±0.15	46.5±2.12	1
39	BB-36p4	4.50±0.10	1.73±0.23	7.30±0.26	2.37 ±0.12	2.62	3.09	1.62	39.13±1.39	26.5±2.12	1
40	BB-38	4.50±0.00	1.53±0.06	7.47±0.35	2.33±0.06	2.94	3.20	1.66	27.37±2.50	31 ±1.41	1
41	BB-42	5.20±0.17	1.80±0.10	7.43±0.06	2.83±0.06	2.89	2.62	1.43	35.76±2.43	51 ±1.41	2
42	BB-61	4.23±0.15	1.57±0.06	7.53±0.06	2.23±0.06	2.70	3.37	1.78	27.99±1.19	51 ±1.41	1
43	BB-111	4.77±0.25	1.60±0.10	7.23±0.25	2.50±0.10	2.98	2.89	1.52	38.29±1.68	31± 1.41	2
44	BB-114	4.57±0.06	1.67±0.06	7.20±0.17	2.37 ±0.12	2.74	3.05	1.58	26.55±1.68	41 ±1.41	1
45	BB-129	4.50±0.10	1.57±0.06	7.37±0.15	2.27±0.06	2.88	3.25	1.64	33.40±3.48	40 ±0.00	1
46	BB-130	4.50±0.10	1.73±0.06	7.07±0.15	2.17±0.06	2.60	3.26	1.57	16.40±3.27	55 ±0.00	1
47	BB-131	4.53±0.06	1.60±0.00	7.80±0.20	2.43 ±0.12	2.83	3.21	1.72	16.54±0.58	35.5±0.71	1
48	BB-134	4.53±0.06	1.67±0.06	7.30±0.10	2.47±0.06	2.72	2.96	1.61	30.75±0.75	60 ±0.00	1

Table-4: Grain dimensions and quality parameters of SM-mutants with Short Slender grain type

S.No.	Entry	KL	KB	KLAC	KBAC	L/B	L/B (AC)	ER	AC	GC	ASV
1	Ti-8	5.67±0.06	1.80±0.10	9.07±0.42	2.90 ±0.10	3.15	3.13	1.60	24.17±1.91	30±0.00	6
2	Ti-17	5.67±0.06	1.80±0.00	9.07±0.40	2.80 ±0.17	3.15	3.25	1.60	6.76±0.28	30 ± 0.00	3
3	Ti-20	5.73±0.06	1.87±0.06	8.00±0.10	2.47±0.06	3.07	3.24	1.40	24.40±2.55	60±0.00	3
4	Ti-30	5.30±0.10	1.63±0.29	8.13±0.45	2.40 ±0.10	3.31	3.39	1.53	16.49±2.98	25±0.00	2
5	Ti-33	5.67±0.15	1.83±0.06	8.83±0.15	2.53±0.06	3.09	3.49	1.56	23.75±14.04	60 ±0.00	2
6	Ti-34	5.77±0.21	1.77±0.06	8.03±0.61	2.57 ±0.25	3.26	3.14	1.39	13.75±0.80	60±0.00	2
7	Ti-52	5.63±0.06	1.67±0.06	7.53±0.35	2.27±0.06	3.38	3.32	1.34	10.49±0.16	46.5±2.12	6
8	Ti-56	5.63±0.06	1.87±0.12	8.90±0.70	2.70±0.17	3.02	3.30	1.58	24.42±3.14	42.5±3.54	5
9	Ti-166	5.27±0.12	1.67±0.06	8.57±0.35	2.47±0.06	3.16	3.47	1.63	27.08±0.06	31 ±1.41	6
10	Ti-167	5.43±0.25	1.63±0.06	9.30±0.26	2.30 ±0.10	3.33	4.05	1.72	18.11±2.20	30 ±0.00	4
11	SB-6	5.00±0.10	1.67±0.06	7.73±0.15	2.30 ±0.00	3.00	3.36	1.75	21.46±5.04	49.5±0.71	1
12	SB-8	4.83±0.12	1.57±0.12	8.00±0.10	2.33±0.06	3.09	3.43	1.66	20.55±0.49	50 ±0.00	1
13	SB-17	5.33±0.21	1.73±0.06	8.00±0.10	2.20 ±0.00	3.08	3.64	1.50	25.52±0.33	51 ±1.41	3
14	SB-18	5.57±0.21	1.80±0.17	8.07±0.06	2.30 ±0.00	3.12	3.51	1.45	14.38±1.72	41.5±16.26	6
15	SB-166	5.60±0.10	1.70±0.00	8.67±0.29	2.33±0.06	3.29	3.71	1.55	11.41±0.03	25.5±0.71	6
16	SM-70	5.73±0.12	1.80±0.00	9.33±0.15	2.63±0.06	3.19	3.55	1.63	5.16±1.61	57.5±3.54	1
17	BB-32p1	4.30±0.00	1.40±0.10	7.77±0.12	2.47 ±0.12	3.08	3.15	1.81	18.61±0.62	30 ±0.00	1
18	BB-93	4.63±0.06	1.50±0.00	7.63±0.21	2.30 ±0.10	3.09	3.32	1.65	27.18±2.96	26.5±2.12	1

Table-5: Grain dimensions and quality parameters of SM-mutants with Long Bold grain type

S.No.	Entry	KL	KB	KLAC	KBAC	L/B	L/B (AC)	ER	AC	GC	ASV
1	Ti-23	6.43±0.06	2.20±0.10	8.00±0.00	2.67 ±0.12	2.93	3.00	1.24	10.06±2.23	30 ±0.00	2
2	Ti-53	6.13±0.06	2.10±0.10	9.43±0.15	3.17 ±0.15	2.93	2.98	1.54	7.35±0.41	25±0.00	5

Table-6: Grain dimensions and quality parameters of SM-mutants with Short bold grain type

S.No	Entry	KL	KB	KLAC	KBAC	L/B	L/B (AC)	ER	AC	GC	ASV
1	Ti-3	5.67±0.15	**2.37±0.06**	8.63±0.21	2.83 ±0.21	2.40	3.06	1.52	23.67±0.47	42.5±3.54	6
2	Ti-4	4.83±0.06	2.00±0.17	6.70±0.10	2.23±0.06	2.43	3.00	1.39	43.34±10.98	35±0.00	3
3	Ti-22	5.47±0.06	2.33±0.38	7.93±0.25	3.13 ±0.21	2.39	2.54	1.45	25.94±0.76	30±0.00	2
4	Ti-42	5.13±0.06	2.17±0.15	7.80±0.26	2.67 ±0.21	2.38	2.94	1.52	6.29±0.84	22.5±3.54	6
5	Ti-46	4.23±0.21	2.07±0.21	6.90±0.36	2.87 ±0.12	2.06	2.41	1.63	8.73±2.11	29±1.41	1
6	Ti-60	3.60±0.10	1.63±0.06	5.80±0.36	2.47±0.21	2.21	2.36	1.61	25.37±0.92	26±1.41	1
7	Ti-62	4.80±0.10	2.03±0.06	7.43±0.12	2.83±0.06	2.36	2.62	1.55	14.42±6.16	60±0.00	7

8	Ti-112	4.93±0.12	2.07±0.12	7.17±0.35	2.73±0.06	2.39	2.62	1.45	26.61±0.65	25±0.00	2
9	Ti-113	5.07±0.25	2.03±0.25	7.87±0.35	2.90 ±0.10	2.53	2.71	1.56	22.82±2.08	60±0.00	6

Note: KL: Kernel length, KB: Kernel breadth, KLAC: Kernel length after cooking, KBAC: Kernel breadth after cooking, L/B: Kernel length / Kernel breadth, L/B(AC): Kernel length after cooking / Kernel breadth after cooking , ER: Elongation Ratio; Amylose Content(AC) /AMY-J, Alkali spreading value(ASV) &Gel consistency (GC) of mutants and SM-Samba Mahsuri/Wild type/BPT-5204: 90 mutants: 89 mutants along with wild type /89+1.

Fig -1 Grain types among SM mutants(LB- Long bold, LS-Long slender, MS-Medium slender, SS-Short slender and SB-Short bold)

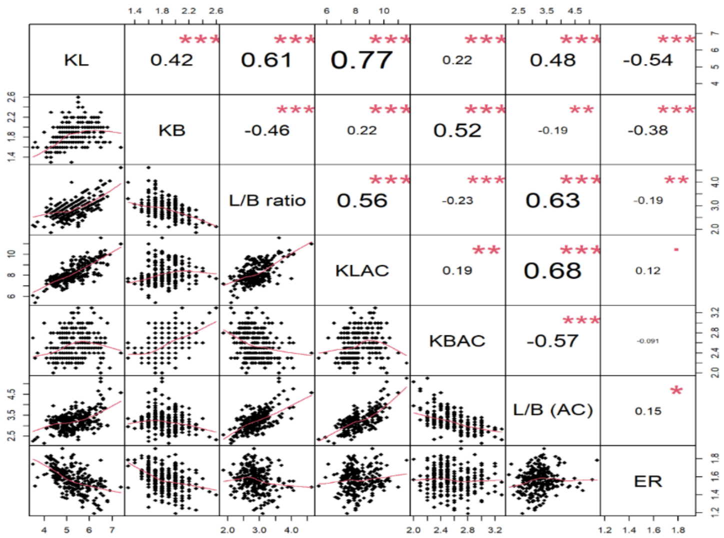

Fig -2: Correlation coefficient among rice grain dimensions before and after cooking

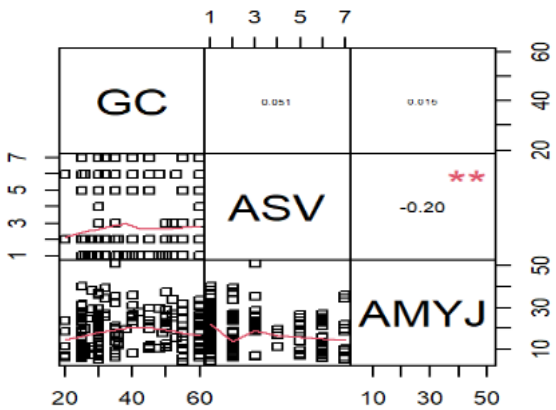

Fig-3 : Correlation coefficient among AC,ASV&GC (AmyJ -Amylose content by Juliano)

Conclusion

Samba Mahsuri mutants have potential for consumer preferences and can be used in future breeding programmes for the improvement of valuable grain quality traits. Some mutants has shown better cooking quality properties than Samba Mahsuri(wild type).After cooking 64 mutants has shown higher kernel length (KLAC) ,54 mutants has shown higher kernel breadth (KBAC) and 6 mutants has recorded higher elongation ratio(ER) ; 52 mutants has shown higher L/B ratio (L/B AC) than Samba Mahsuri. Mutagenesis has created novel variations in morphological, physiological and biotic stress tolerance traits (Gopi Potupureddy et.al,2021) ;in the same way mutagenesis has influenced the quality traits too.

Highly preferable grain quality parameters such as intermediate amylose content is found in 20(19+1)mutants along with Samba Mahsuri(BPT-5204); intermediate gelatinization temperature shown in 15 mutants whereas Samba Mahsuri has shown high gelatinization temperature and soft gel consistency recorded in 14 mutants whereas Samba Mahsuri has shown medium gel consistency.

Further the mutants has to be evaluated for sensory analysis and organoleptic test to know the consumers accepatance .

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