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GENETIC VARIABILITY AND INTER-TRAIT ASSOCIATION FOR COOKING AND MICRONUTRIENT (Fe& Zn) TRAITS IN ADVANCE LINES OF KALANAMAK AROMATIC RICE

S. Kumar[1*], I. D. Pandey[2,] S. A. Rather[2] and H. Rewasia[2]

[1]ICAR –Indian Institute of Agricultural Biotechnology, Ranchi-834010, India
[2]Department of Genetics and Plant Breeding, G.B.P.U.A. & T. Pantnagar (U.S. Nagar) Uttarakhand-263145, India
[*]Corresponding author email: sudhiraaidu2006@gmail.com

ABSTRACT

The present investigation comprised of 48 advance lines of Kalanamak aromatic rice with three different checks namely Pusa Basmati-1, Pant Sugandh Dhan-17 and 3131-SN, to assess the extent of genetic variability and inter trait association for thirteen cooking quality and two micronutrients (Fe & Zn) traits. The magnitude of phenotypic co-efficient of variation (PCV) in general was found higher than the genotypic co-efficient of variation (GCV) for all the characters studied but the difference was very less, indicating minor influence of environment. Based on mean content, genotypes namely, PMS-33, PMS-27, PMS-52, PMS-38 and PMS-23 were found promising for several desirable cooking quality traits such as kernel length, kernel length-breadth ratio and cooked kernel length. High heritability associated with high genetic advance was found for traits *viz*., kernel length-breadth ratio, cooked kernel length, aroma and for micro-nutrient traits (Fe & Zn). These quality traits were predominantly under the control of additive gene action. The genotypic correlation was found to be higher than the corresponding phenotypic correlation coefficient, and it showed strong inherent association between different quality and micronutrient traits. The high positive association was found between kernel length and kernel length breadth ratio, milling recovery (%) and head rice recovery followed by hulling recovery (%) and head rice recovery (%). Iron content showed highly significant positive association with zinc content indicating co-segregation of concerned factors.

Key words: Kalanamak; variability; quality; micronutrient; correlation;

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the important principal staple food crops for more than half of world population. More than 90 percent of the world rice is grown and consumed in Asia where nearly 60 percent of the world population live and survive. Along with yield, cooking & nutritional quality has also become a primary consideration in rice breeding programs not only in India but also in various rice growing countries across the world. Grain quality of rice plays an important role in consumer acceptability since rice is mainly consumed as whole grains especially in Asia (Seraj *et al*., 2013). The cooking quality preferences vary within the country, within ethnic groups and from one country to another within different geographical regions (Shobha Rani *et al*., 2006). Rice grain quality is primarily assessed based on physical properties such as, milling quality, head rice recovery, chalkiness, grain size and shape, and grain colour, premium quality traits such as aroma, and cooking properties (Dela-Cruz and Khush, 2000). The growing income and food diversification in some Asian and European countries have led consumers to prefer better quality rice, while people in some parts of the world seek improved nutrition. Micronutrient malnutrition, and particularly Fe and Zn deficiency affected over three billion people worldwide, mostly in developing countries (Welch and Graham, 2004). Therefore, in this era, research work should be more focused on enhancement of micronutrient along with cooking quality traits in rice to meeting the demand and combat the malnutrition deficiency. Aromatic rice varieties include long grain basmati, Jasmine rice and small to medium scented indigenous rice of India. Kalanamak is one of the finest quality aromatic rice of India, famous for taste, palatability, and aroma and it surpasses basmati rice in most of cooking quality traits except grain length. Thus, characterization of Kalanamak aromatic rice for various cooking and micronutrient traits is of prime importance in order to identify genotypes with excellent cooking quality and rich in essential micro-nutrient. In the present investigations, forty eight advance lines of Kalanamak aromatic rice emanated from varietal hybridization of Kalanamak x Kalanamak accessions (3131-SN, 3216-SN & 3327-SN) and Kalanamak x Pusa Basmati-1, along with three checks (Pusa Basmati-1, Pant Sugandh-17 & 3131-SN), were studied and analyzed to assess the magnitude of genetic variability and to estimate inter-trait association amongst thirteen cooking quality and two micronutrient traits (Fe & Zn content).

MATERIALS AND METHODS

The Experimental material for present study compromised of 48 advance lines of Kalanamak aromatic rice genotypes along with three different checks (3131-SN, PB-1 & PSD-17). The experiment was conducted in augmented block design with 6 blocks at organic Farm of Breeder seed production Centre, Pantnagar, (Uttarakhand). Every block had 8 entries and the checks were replicated in each block once. Each plot consisted of 2 rows of 3m length and maintained row to row and plant to plant distance of 20 cm and 15 cm, respectively. Grains were harvested, in 2nd week of December 2014 and sun dried for four days and utilized for cooking and micronutrient quality parameters analysis. Cooking quality and micro-nutrient (Fe & Zn) contents were determined in the rice quality lab of department of Genetics and Plant Breeding and Micro-nutrient lab of department of soil science, college of Agriculture, Pantnagar. Advance lines have been generated through varietal hybridization of Kalanamak x Kalanamak accessions (3131-SN, 3119, and 3122) and Kalanamak x Pusa Basmati-1.

Rough rice samples were dehulled with a Satake laboratory sheller. The sample was poured into the hopper. Entire de-husked kernels were used for milling for a period of 2 minutes by KETT type T-2. Broken and unbroken rice were separated manually. Three fourth to whole kernels were taken as head rice and head rice recovery was calculated by dividing weight of head rice to total weight of brown rice. Various cooking quality traits like alkali digestion value (Little *et al*., 1958), gel consistency (Cagampang *et al.,*1973), amylose content (Sowbhagya and Bhattacharya, 1971), kernel length, kernel breadth, cooked kernel length, cooked kernel breadth, kernel elongation ratio (Azees and Shafi, 1966**)** and aroma were also determined (Juliano and Perez, 1984).Iron and Zinc contents in brown rice were estimated using atomic absorption spectrophotometer (Varian Model) after wet digestion of the sample (Piper, 1950). The data were analyzed using augmented design to determine statistical significance (Panse and Shukhatme, 1969)**.** The phenotypic and genotypic coefficients of variation (PCV and GCV), Heritability (h^2) and expected genetic advance in terms of per cent of mean (GA %) were calculated as suggested by Allard (1960). The estimation of phenotypic and genotypic correlation coefficient was determined in the order to determine the inter-trait association of different cooking and micronutrient traits (Searle, 1961).

RESULTS AND DISCUSSIONS

Genetic variability in any crop is pre-requisite for selection of superior genotypes over the existing cultivars for various agronomic and quality traits. Analysis of variance under augmented design revealed highly significant and exploitable variability among tested genotypes for all the cooking quality and micro-nutrient traits and non-significant for the blocks which indicated the presence of adequate variability in the material under study (Table 1). The general mean (tested genotypes and checks), range and coefficient of variation for the different cooking and micronutrient traits are presented in Table 2**.**

The Kernel length ranged from 3.66 to 5.62 mm with general mean of 4.32 mm and cooked kernel length range was found from 8.02 to 14.26 mm with the general mean of 10.07 mm. Kernel elongation ratio (KER) range was found from 1.87 to 2.99 with the general mean of 2.34. Kernel elongation ratio (KER) is a major quality determinant character for aromatic rice. The mean values of cooking quality and micronutrient traits of forty eight advance lines along with three checks are presented in Table 3.Based on mean performance, genotypes namely, PMS-33, PMS-27, PMS-52, PMS-38 and PMS-23 were found promising for several desirable cooking quality traits such as kernel length, kernel length-breadth ratio and cooked kernel length with intermediate amylose and gelatinization temperature. These genotypes were at par with basmati rice possessing Kalanamak rice background. These genotypes could be registered as genetic stock or may be utilized for development of fine and super fine Kalanamak aromatic rice varieties. The mean value of intermediate amylose with pleasant strong aroma is of paramount importance in respect of quality rice breeding. Aroma development is also influenced by both genetic factors and environment. The major aromatic compound responsible for aroma is considered is 2-acetyl-1-pyrroline (Buttery *et al.,* 1986). In the present studies most of the genotypes were analyzed for intermediate amylose content and mild to very strong aroma.

Traditional indigenous Kalanmak aromatic rice is reported to be high (35 µg/g in unpolished rice) for iron content (Ravindra Babu *et al*, 2013). In the present investigation, iron content in brown rice ranged from 16.48 - 41.33 µg/g with the general mean of 28.37µg/g and Zinc content range was found from 15.63 - 46.94 µg/g with the general mean of 25.59 µg/g. Genotypes such as PMS-13 and PMS-46 were observed significantly higher for both Iron and Zinc content than the corresponding checks. Enhancement of micronutrient levels of staple crops through biological processes, such as plant breeding and genetic engineering is referred as biofortification and it could be effective in reducing the problems of malnutrition (Bouis, 2002). The estimates of genetic parameters of variability *viz*., phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability in broad sense and genetic advance as percent of mean are presented in Table 4. The phenotypic coefficient of variation (PCV) in general was higher than the genotypic coefficient of variation (GCV) for all traits. The magnitude of difference between GCV and PCV was very narrow indicating less environmental influence and predominant genetic factors involved in expression of cooking and micronutrient traits of different advanced lines of Kalanamak aromatic rice. Vivekanandan and Giridharan (1998) also reported closeness of GCV and PCV for different cooking quality traits indicating higher resistance to major environmental influence.

High and moderate estimates of PCV and GCV were observed for Zinc content, Iron content, cooked kernel length and kernel length-breadth ratio. This indicates the existence of sufficient genetic base among the genotypes taken for study and possibility of genetic improvement through direct selection of these traits. Similar findings were reported by Sala *et al*. (2012) for Iron and Zinc and Patil *et al*. (2003) for kernel length after cooking. The estimates of PCV and GCV were low for traits like kernel length, kernel breadth, cooked kernel breadth, kernel elongation ratio, hulling recovery (%), milling recovery (%), head rice recovery (%), alkali spreading value, gel consistency and amylose content. Subbaiah *et al*. (2011) similarly reported low value of PCV and GCV for hulling recovery (%), milling recovery (%), head rice recovery (%), gel consistency and amylose content in aromatic rice. High heritability coupled with high genetic advance were observed for cooking quality traits *viz.* cooked kernel length, kernel length breadth ratio and micronutrient traits, *viz.,* Iron and Zinc content. Similar finding was reported for cooked rice kernel length ratio by Chakraborty *et al.* (2009) for Iron content by Sala *et al.* (2012) and Zinc content by Gangashetty *et al.* (2013). The characters showing high to moderate GCV and PCV, high heritability coupled with high genetic advance indicated that they are governed by additive gene action and breeding method based on progeny testing and mass selection could be useful in improving these traits.

High heritability coupled with moderate genetic advance were observed for amylose content, gel consistency, alkali spreading value, head rice recovery, milling recovery and kernel elongation ratio. Similar finding was reported for amylose content by Nayak *et al.,* (2004), for gel consistency by Chakraborty *et al.* (2009) and for alkali spreading value and kernel elongation ratio by Rathi *et al.* (2010). High heritability coupled with low genetic advance was reported for kernel breadth and moderate heritability with low genetic advance was recorded for cooked kernel breadth. Low heritability coupled with low genetic advance was recorded for hulling recovery (%). This indicated that that kernel breadth, cooked kernel breadth and hulling recovery were predominantly governed by non-additive gene action (dominant or epistasis) in Kalanamak advance lines. The characters showing high heritability along with moderate or low genetic advance can be improved by intermating superior genotypes of segregating population developed from combination breeding (Samadia, 2005).

The estimates of genotypic correlation coefficient are essential in evaluating the possibility of simultaneous improvement of many characters or improvement of complex traits of agronomical and other quality traits. In present investigation, phenotypic and genotypic correlation coefficient was studied with cooking and micronutrients traits (Table 5**)**. In general, the magnitude of estimated genotypic correlation coefficient was higher than the corresponding phenotypic correlation coefficients. This showed a strong inherent association among the quality traits under investigation.

Kernel length showed significant positive correlation with Kernel length breadth ratio (KL/KB) and cooked kernel length both at genotypic and phenotypic level and it exhibited positive association with Iron content, and gel consistency only at genotypic level. However, on the other hand it showed negative association with hulling recovery (%) and head rice recovery (%). Similar to our finding, Singh *et al*. (2017) also reported, significant and positive association of kernel length with cooked kernel length and kernel length breadth ratio. Kernel breadth was found to be negatively associated with kernel length breadth ratio and gel consistency and positively associated with hulling recovery (%) and amylose content at genotypic level only. Kernel length breadth ratio (KL/KB) was significantly and positively associated with cooked kernel length and Iron content (at both phenotypic and genotypic level). KL/KB also had negative association with head rice recovery, head rice recovery and amylose content. Hulling recovery (%) showed highly positive association with milling recovery (%), head rice recovery (%) at both genotypic and phenotypic level. However, it showed negative association with Iron content at the level of both genotypic and phenotypic levels and gel consistency and Zinc content at genotypic level only. In the present study, the positive significant association of hulling recovery (%) with milling recovery (%) and head rice recovery (%) indicated that the genotypes with higher hulling percent also showed higher estimates for milled rice and head rice recovery. Similar results were reported by several researchers like Chauhan *et al*. (1995), Nayak *et al*. (2003) and Nirmala Devi *et al.* (2015). Hulling recovery (%), milling recovery (%) and Head rice recovery (%) are important quality attributes for rice that enhances commercial success of a variety. Simultaneous improvement of these three quality traits could be achieved through the selection of a single trait is either hulling percent or milling percent or head rice recovery. Head rice recovery showed significant and positive association with amylose content and significant and negative association with Iron and Zinc content. Madhubabu *et al*. (2017) also reported significant positive correlation between head rice recovery and

Table 1. Analysis of variance (ANOVA) for different quality characters

S.No	Source of variation	df	Mean sum of squares														
			KL	KB	KL/KB ratio	CKL	CKB	KER	HR (%)	MR (%0	HRR (%)	ASV	GC	A	AC	Fe	Zn
1	Block (eliminating Check+Var.)	5	0.012	0.001	0.009	0.113	0.026	0.005	7.899	4.227	3.3979	0.0811	7.6854	0.000	0.5139	2.9292	3.4520
2	Entries (ignoring Blocks)	50	0.883**	0.012**	0.402**	2.27**	0.090*	0.127**	17.568*	31.758**	62.243**	0.439**	53.955**	0.632**	3.833**	61.057**	41.717**
3	Checks	2	4.162**	0.036**	2.308**	12.157**	0.722**	0.044**	37.203*	57.055**	457.408**	1.407**	220.191**	2.000**	15.528**	329.420**	5.738
4	Varieties	47	0.221**	0.011**	0.1015**	1.843**	0.053	0.065**	8.609	25.093	32.658**	0.2178	47.500*	0.581**	3.332**	36.525**	39.654**
5	Checks vs. Varieties	1	25.43**	0.041**	10.734**	2.462**	0.544**	3.209**	399.387**	294.414	662.380*	8.938**	24.885**	0.278**	3.970*	677.350**	210.642**
6	ERROR	10	0.019	0.001	0.007	0.071	0.023	0.002	6.362	4.774	3.497	0.038	12.941	0.001	0.780	3.118	3.452

* Significant at 5% level of probability; ** Significant at 1% level of probability; (KL- Kernel length, KB-Kernel breadth, KL/KB-Ratio of Kernel length and kernel breadth, KER-Kernel elongation ratio, HR- Hulling Recovery, MR- Milling recovery, HRR- Head rice recovery, ASV-Alkali spreading value, GC- Gel consistency , A- Aroma, AC-Amylose content, Fe – Iron, Zn- Zinc)

Table 2. General Mean, range, Coefficient of variation and least significant difference for different cooking and micronutrient traits of Kalanamak advanced lines

S. No.	Traits	Genotype		Checks			CV%	CM	AVSB	AVDB	AVAC
		General mean	Range	3131-SN	Pusa Basmati-1	Pant Sugandh Dhan 17					
1	Kernel length (mm)	4.32	3.66-5.62	4.76	6.12	6.27	13.42	0.18	0.43	0.50	0.38
2	Kernel breadth (mm)	1.77	1.58-2.19	1.80	1.66	1.67	5.80	0.03	0.08	0.09	0.07
3	Kernel length/breadth ratio	2.45	2.05-3.51	2.64	3.69	3.74	15.83	0.11	0.27	0.31	0.24
4	Cooked kernel length (mm)	10.07	8.02-14.26	8.92	11.67	10.94	13.37	0.34	0.84	0.97	0.74
5	Cooked kernel breadth (mm)	2.76	2.47-3.96	2.96	2.35	2.36	9.35	0.20	0.48	0.55	0.42
6	Kernel elongation ratio	2.34	1.87-2.99	1.88	1.91	1.74	12.02	0.06	0.15	0.18	0.14
7	Hulling recovery (%)	79.69	71.56-85.56	76.74	71.77	73.97	4.55	3.24	7.95	9.18	7.01
8	Milling recovery (%)	68.90	58.81-82.14	67.71	62.56	62.19	7.52	2.81	6.88	7.95	6.07
9	Head rice recovery (%)	59.60	47.22-71.66	62.42	46.04	48.99	10.36	2.41	5.89	6.80	5.20
10	Alkali spreading value	5.27	4.30-6.12	5.54	6.32	6.42	10.16	0.25	0.62	0.71	0.54
11	Gel consistency (mm)	77.42	61.81-93.50	82.92	73.68	71.53	9.07	4.63	11.34	13.09	10.00
12	Aroma	1.33	1.00-2.00	1.00	2.00	1.00	33.33	0.05	0.11	0.26	0.20
13	Amylose content (%)	20.87	17.79-24.41	19.57	22.25	22.44	9.16	1.14	2.78	3.21	2.45
14	Fe(µg/g)	28.37	16.48-41.33	29.34	14.88	19.32	22.43	2.27	5.56	6.43	4.91
15	Zn(µg/g)	25.59	15.63-46.94	28.93	29.15	30.72	24.38	2.39	5.85	6.76	5.16

CM = Least significant difference between the means of two check varieties; AVSB = Least significant difference between adjusted values of two selections in the same block
AVDB = Least significant difference between adjusted values of two selections in the different blocks; AVAC = Least significant difference between an adjusted selection value and a check mean

Table 3. Mean value of forty eight Kalanamak Advanced lines for different cooking and micronutrient traits.

Geno-types	Pedigree	KL (mm)	KB (mm)	KL /KB	CKL (mm)	CKB (mm)	KER (mm)	HR (%)	MR (%)	HRR	ASV	GC (mm)	A	AC (%)	Fe (µg/g)	Zn (µg/g)
PMS-29	3131SN x PB-1	3.76	1.79	2.11	8.02	2.57	2.13	85.00	82.14	61.59	5.25	81.80	2.00	21.59	25.064	26.20
PMS-15	3131-SN x 3327-SN	4.26	1.89	2.26	10.62	2.70	2.49	79.36	61.60	57.47	5.59	75.80	1.00	22.87	20.464	21.75
PMS-03	3131-SN x 3327-SN	3.81	1.69	2.26	8.62	2.70	2.26	81.29	74.24	66.47	5.09	73.30	0.00	24.04	32.964	25.40
PMS-81	3131-SN x 3327-SN	3.88	1.71	2.28	8.36	2.55	2.15	84.12	77.29	67.47	5.27	84.58	1.00	21.12	27.914	21.15
PMS-04	3131-SN x 3327-SN	4.16	1.69	2.47	10.12	2.47	2.43	83.14	65.59	59.89	5.75	76.80	1.00	23.44	30.814	33.10
PMS-46	3131-SN x 3327-SN	4.46	2.19	2.05	10.72	2.77	2.40	82.19	68.39	61.42	4.92	70.80	2.00	21.44	36.064	34.40
PMS-45	3131-SN x 3327-SN	4.31	1.74	2.49	10.12	2.72	2.34	80.79	73.39	58.87	4.59	72.80	2.00	17.80	24.664	29.15
PMS-24	3131-SN x PB-1	3.88	1.89	2.06	9.32	2.70	2.40	83.14	65.59	56.87	4.42	82.80	2.00	18.20	28.714	26.50
PMS-18	3216-SN x 3327-SN	3.76	1.69	2.24	11.17	2.72	3.00	82.46	73.76	61.66	5.03	70.50	0.00	19.85	22.681	19.72
PMS-51	3216-SN x 3327-SN	3.81	1.69	2.27	8.95	2.72	2.36	78.51	63.97	51.61	5.36	76.50	1.00	19.32	30.731	25.47
PMS-78	3216-SN x 3327-SN	4.16	1.81	2.31	8.72	2.64	2.10	82.66	75.27	65.43	4.86	81.50	0.00	22.87	16.481	20.72
PMS-55	3216-SN x 3327-SN	4.16	1.69	2.47	8.97	2.64	2.16	78.31	61.77	51.55	4.86	84.50	1.00	19.42	40.531	32.92
PMS-48	3131SN x PB-1	4.36	1.79	2.45	9.57	2.47	2.20	85.39	73.97	66.56	4.53	74.50	2.00	20.27	16.881	25.07
PMS-86	3216-SN x 3327-SN	4.46	1.79	2.50	9.37	2.77	2.10	85.56	77.08	71.66	6.03	79.50	0.00	20.12	20.881	29.15
PMS-26	3131SN x PB-1	4.36	1.69	2.59	10.67	2.57	2.46	75.51	64.02	51.51	4.86	93.50	2.00	17.92	30.881	34.87
PMS-25	3131SN x PB-1	4.56	1.59	2.87	10.27	2.67	2.26	79.56	65.14	55.91	4.36	85.50	2.00	18.17	33.681	46.57
PMS-33	3131SN x PB-1	5.06	1.70	2.97	10.61	2.70	2.10	75.41	65.637	53.22	4.35	88.73	2.00	18.91	29.081	22.15
PMS-07	3216-SN x 3327-SN	4.11	1.90	2.15	8.91	2.60	2.18	77.87	69.637	58.27	5.35	62.73	0.00	24.12	20.631	25.55
PMS-14	3216-SN x 3327-SN	4.16	1.80	2.30	10.36	2.70	2.50	84.72	74.637	69.02	5.52	67.73	0.00	21.07	30.381	24.25
PMS-34	3131SN x PB-1	4.11	1.70	2.41	9.16	2.72	2.24	83.67	64.717	57.71	4.68	71.73	1.00	21.07	37.881	24.75
PMS-47	3131-SN x 3327-SN	4.41	1.96	2.24	12.21	2.50	2.77	79.77	65.837	60.33	4.68	68.73	2.00	22.77	24.681	27.05
PMS-17	3216-SN x 3327-SN	4.07	1.70	2.39	10.11	3.00	2.49	82.17	73.157	64.43	5.35	69.73	1.00	21.73	18.581	16.10
PMS-50	3131SN x PB-1	4.86	1.70	2.85	10.51	2.80	2.16	81.57	71.397	64.01	5.52	72.73	1.00	21.57	29.431	33.80
PMS-72	3216-SN x 3327-SN	3.66	1.60	2.28	10.31	2.70	2.82	82.22	69.187	61.82	5.85	78.73	0.00	22.77	27.931	19.70
PMS-58	3216-SN x 3327-SN	4.12	1.81	2.27	12.31	3.01	2.96	76.05	66.464	56.70	5.80	88.61	1.00	20.83	37.797	29.39
PMS-88	3216-SN x 3327-SN	3.87	1.83	2.10	8.80	2.76	2.25	77.51	69.674	59.46	5.47	74.61	0.00	22.18	33.747	25.14
PMS-21	3131SN x PB-1	4.67	1.71	2.72	11.30	2.81	2.41	78.06	69.904	49.81	5.14	72.61	1.00	21.63	25.997	24.99
PMS-10	3216-SN x 3327-SN	3.87	1.71	2.25	10.18	2.71	2.60	78.36	64.54	55.98	4.97	75.11	0.00	19.31	20.797	23.54
PMS-42	3216-SN x 3327-SN	4.12	1.81	2.27	8.90	2.76	2.14	83.26	73.24	67.11	4.80	81.61	2.00	18.23	29.15	21.84
PMS-35	3216-SN x 3327-SN	3.77	1.81	2.07	10.40	3.10	2.73	80.11	74.52	63.10	5.47	73.61	2.00	19.73	27.40	20.84
PMS-22	3131SN x PB-1	4.37	1.77	2.47	10.50	2.91	2.39	84.36	76.04	69.11	4.30	75.61	1.00	18.88	17.80	22.15
PMS-13	3216-SN x 3327-SN	4.97	1.71	2.90	11.50	2.61	2.31	76.26	64.44	50.76	5.97	79.61	1.00	18.09	37.70	46.94
PMS-49	3131SN x PB-1	4.68	1.81	2.57	11.183	2.50	2.39	81.07	61.95	55.17	6.12	73.81	2.00	22.87	27.20	20.77
PMS-09	3216-SN x 3327-SN	4.20	1.91	2.18	9.58	2.75	2.28	79.92	67.74	61.13	5.79	61.81	2.00	24.42	23.20	25.97
PMS-30	3131SN x PB-1	3.75	1.71	2.18	10.58	2.90	2.81	76.44	62.87	54.18	5.62	79.81	2.00	22.57	26.90	15.63
PMS-27	3131SN x PB-1	5.45	1.81	3.01	13.08	3.098	2.40	79.63	71.49	57.88	5.29	91.81	1.00	19.89	33.05	21.87
PMS-03	3216-SN x 3327-SN	3.80	1.71	2.201	8.68	2.90	2.28	79.17	72.34	64.03	5.29	72.31	1.00	24.07	31.23	24.47
PMS-38	3131SN x PB-1	5.25	1.63	3.211	9.86	2.91	1.88	72.99	61.33	47.23	4.79	82.81	2.00	17.87	29.55	25.07
PMS-32	3131SN x PB-1	4.47	1.81	2.451	9.08	2.60	2.03	77.24	68.55	55.77	4.95	91.81	2.00	18.10	36.14	28.27
PMS-31	3131SN x PB-1	4.65	1.76	2.631	9.18	2.50	1.98	78.47	69.24	67.08	5.94	74.81	2.000	19.47	30.05	19.32

PMS-28	3131SN x PB-1	4.50	1.69	2.657	10.27	2.81	2.30	79.12	71.68	60.17	5.94	77.53	1.000	23.06	33.23	20.37
PMS-23	3131SN x PB-1	5.40	1.79	3.007	14.62	4.10	2.72	72.49	58.81	50.42	5.27	74.53	1.000	20.28	26.88	16.27
PMS-87	3216-SN x 3327-SN	4.30	1.83	2.347	8.78	2.99	2.06	79.41	72.82	67.39	5.70	73.03	1.000	21.38	26.58	26.02
PMS-37	3131SN x PB-1	4.02	1.79	2.247	9.12	2.90	2.29	79.45	68.81	60.42	5.10	76.53	2.000	21.81	24.68	27.87
PMS-01	3131-SN x 3327-SN	4.10	1.79	2.287	9.17	2.70	2.26	76.58	64.15	56.96	5.27	86.53	1.000	19.43	26.33	18.92
PMS-52	3131SN x PB-1	5.62	1.59	3.517	13.02	2.70	2.33	74.91	64.26	58.16	5.94	77.53	2.000	21.28	41.33	28.87
PMS-20	3131SN x PB-1	4.60	1.79	2.567	8.67	2.92	1.89	71.56	63.57	55.58	5.94	71.53	1.000	23.56	28.43	26.12
PMS-83	3216-SN x 3327-SN	4.33	1.77	2.447	9.12	2.70	2.12	78.04	71.24	62.51	5.92	83.10	1.000	20.64	28.79	22.27
3131-SN	C-1	4.76	1.80	2.645	8.92	2.96	1.88	76.74	67.71	62.42	5.54	82.93	1.000	19.57	29.34	28.93
PB-1	C-2	6.12	1.66	3.692	11.67	2.35	1.91	71.78	62.56	46.043	6.32	73.69	2.000	22.26	14.87	29.15
PSD-17	C-3	6.28	1.67	3.745	10.94	2.36	1.75	73.97	62.20	48.99	6.43	71.56	1.000	22.44	19.32	30.73
Mean		4.40	1.76	2.51	10.10	2.75	2.31	79.36	68.62	59.18	5.32	77.34	1.21	20.906	27.95	25.83
Std. Dev.		0.59	0.10	0.40	1.351	0.257	0.277	3.61	5.16	6.129	0.541	7.02	0.749	1.915	6.27	6.30
Std. Error		0.08	0.01	0.06	0.19	0.036	0.04	0.50	0.72	0.86	0.08	0.98	0.10	0.27	0.88	0.88
C. V. %		13.42	5.80	15.84	13.37	9.35	12.02	4.55	7.52	10.36	10.16	9.07	62.61	9.16	22.44	24.39

(KL- Kernel length, KB-Kernel breadth, KL/KB- Ratio of Kernel length and kernel breadth, KER-Kernel elongation ratio, HR - Hulling Recovery, MR -Milling recovery, HRR- Head rice recovery , ASV-Alkali spreading value, GC- Gel consistency , A- Aroma, AC-Amylose content, Fe – Iron, Zn- Zinc

Table 4.Phenotypic and genotypic coefficient of variation, heritability and genetic advance (as % of mean) among Kalanamak advanced lines of rice for quality traits

S. No.	Traits	PCV(%)	GCV(%)	Heritability (%)	Genetic advance (as % of mean)
1	Kernel length (mm)	9.74	9.21	89.40	17.93
2	Kernel breadth (mm)	5.22	5.01	92.4	9.94
3	Kernel length/breadth ratio	11.60	11.05	90.8	21.71
4	Cooked kernel length (mm)	11.98	11.69	95.1	23.49
5	Cooked kernel breadth (mm)	7.83	5.59	50.8	8.21
6	Kernel elongation ratio	9.73	9.50	95.3	19.12
7	Hulling recovery (%)	3.57	1.67	21.7	1.60
8	Milling recovery (%)	6.60	5.79	76.9	10.46
9	Head rice recovery (%)	8.61	8.02	86.70	15.38
10	Alkali spreading value	8.02	7.12	78.6	13.00
11	Gel consistency (mm)	8.17	6.72	67.7	11.39
12	Aroma	29.23	27.60	91.24	56.44
13	Amylose content (%)	7.98	6.77	71.9	11.83
14	Fe(µg/g)	19.07	18.03	89.4	35.11
15	Zn(µg/g)	22.04	20.80	89.1	40.47

Table 5. Estimates of phenotypic and genotypic correlation coefficient for cooking quality and micronutrients traits

Traits		KL	KB	KL/KB	CKL	CKB	KER	HR (%)	MR (%)	HRR (%)	ASV	GC	A	AC	Fe	Zn
KL	P	1.000	-0.073	0.901**	0.615**	0.156	-0.251	-0.292*	-0.248	-0.284*	-0.025	0.199	0.223	-0.268	0.278	0.229
	G	1.000	-0.091	0.908**	0.638**	0.231	-0.228	-0.798**	-0.381**	-0.296*	-0.088	0.364*	0.236	-0.383**	0.319*	0.237
KB	P		1.000	-0.494**	-0.016	0.038	0.015	0.196	0.079	0.183	-0.060	-0.254	0.117	0.165	-0.204	-0.034
	G		1.000	-0.498**	-0.016	0.203	0.021	0.395**	0.081	0.251	-0.003	-0.443**	0.122	0.304*	-0.274	-0.078
KL/KB	P			1.000	0.538**	0.109	-0.228	-0.345*	-0.258	-0.323*	-0.002	0.276	0.167	-0.306*	0.344*	0.233
	G			1.000	0.553**	0.049	-0.212	-0.855**	-0.371*	-0.378**	-0.087	0.509**	0.175	-0.477**	0.421**	0.265
CKL	P				1.000	0.403**	0.601**	-0.273	-0.360*	-0.314*	0.066	0.056	0.015	-0.095	0.165	0.022
	G				1.000	0.581**	0.605**	-0.393**	-0.379**	-0.324*	0.031	0.074	0.015	-0.109	0.155	0.006
CKB	P					1.000	0.301*	-0.196	-0.060	-0.101	-0.122	-0.093	-0.267	-0.028	-0.097	-0.198
	G					1.000	0.442**	0.054	-0.064	-0.206	-0.225	0.265	-0.378*	-0.278	-0.021	-0.298
KER	P						1.000	-0.046	-0.196	-0.123	0.117	-0.132	-0.192	0.135	0.075	-0.207
	G						1.000	0.166	-0.142	-0.118	0.132	-0.222	-0.197	0.196	-0.107	-0.236
HR (%)	P							1.000	0.682**	0.720**	0.035	-0.219	-0.024	0.126	-0.321*	-0.225
	G							1.000	0.767**	0.824**	0.189	-0.686**	-0.051	0.618**	-0.494**	-0.287*
MR(%)	P								1.000	0.777**	0.063	-0.141	-0.135	0.125	-0.349*	-0.254
	G								1.000	0.820**	0.071	-0.202	-0.154	0.267	-0.357*	-0.248
HRR(%)	P									1.000	0.189	-0.267	-0.167	0.243	-0.343*	-0.283*
	G									1.000	0.169	-0.377**	-0.178	0.365*	-0.315*	-0.231
ASV	P										1.000	-0.217	-0.308*	0.479**	0.105	-0.025
	G										1.000	0.183	-0.347*	0.485**	0.166	-0.037
GC	P											1.000	0.219	-0.547**	0.367*	0.102
	G											1.000	0.267	-0.419**	0.383**	0.166
A	P												1.000	-0.344*	0.162	0.202
	G												1.000	-0.405**	0.171	0.214
AC	P													1.000	-0.191	-0.183
	G													1.000	-0.154	-0.284*
Fe	P														1.000	0.450**
	G														1.000	0.482**

(KL- Kernel length, KB-Kernel breadth, KL/KB-Ratio of Kernel length and kernel breadth, KER-Kernel elongation ratio, HR- Hulling Recovery, MR-Milling recovery, HRR- Head rice recovery, ASV-Alkali spreading value, GC- Gel consistency, A- Aroma, AC-Amylose content, Fe – Iron content , Zn- Zinc content) (*** & ** indicates significance at 5% and 1% probability levels, respectively)** amylose content. Alkali spreading value was found to be positively associated with amylose content and negatively associated with aroma. Gel consistency showed significant and positive association with Iron content and negative association with amylose content. The amylose content is a chemical quality trait that determines the texture of cooked rice. Varieties with intermediate amylose content and soft gel consistency are preferred by most rice consumers. In present investigation, the significant negative association between these two chemical quality traits (gel consistency and amylose content) was found. Thus, it indicated that for the selection of quality rice, one must first focus on selecting intermediate amylose content followed by gel consistency test as one trait is not sufficient enough to determine the softness of the rice after cooking. Iron content showed highly significant positive association with Zinc content. Similarly, positive association of iron and zinc content was also reported by Archna *et al*. (2018). Graham *et al*.(1999) reported significant positive correlation between Iron and Zinc in rice, wheat and beans. Furthermore, Stangoulis *et al.* (2007) too reported significant positive correlation between Zinc and iron content in double haploid rice population indicating co-segregation of concerned factors.

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