Received: 05 Sep 2022 | Revised: 10 May 2023 | Accepted: 29 May 2023

Electronic Journal of Plant Breeding

Research Article

Characterisation, genetic parameters of variation and correlation studies in Molakolukulu Rice cultivars of Andhra Pradesh, India

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Abstract
The present investigation was carried out to study the genotypic ad phenotypic coefficient of variation and character association in 25 molakolukulu rice genotypes. It revealed significant differences among the genotypes with respect to yield and quality. High PCV and GCV were recorded for gel consistency followed by alkali spreading value, zinc content and oil content, the estimates of heritability coupled with genetic advance as per cent of mean were high for the characters *viz*., plant height, flag leaf length, filled grains per panicle, gel consistency, iron content and oil content. Correlation studies revealed that filled grains per panicle and flag leaf breadth were found to possess significant positive association with grain yield per plant. Among the quality traits, alkali spreading value exhibited positive significant association with amylose content. Path analysis revealed that number of filled grains per panicle exhibited positive direct effect on grain yield per plant. Among the quality traits, alkali spreading value had positive direct effect on amylose content. Therefore, selection in favour of filled grains per panicle and flag leaf breadth would improve grain yield per plant. Alkali digestion values, on the other hand would be useful as a selection criterion for amylase content in molagolukulu rice.

Keywords: Variability, Correlation, Path analysis, Molagolukulu rice

INTRODUCTION

Rice is the staple food crop in India. Molakolukulu rice is an indigenous group of rice varieties of Andhra Pradesh traditionally grown in the districts of Nellore, Chittoor, Prakasam, Kadapa and Guntur districts. In spite of being famous for their good cooking, eating and keeping quality, the area under these varieties has been reduced drastically owing to low productivity and is now being grown in only about 45000 acres.

The Molagolukulu rice varieties are characterised by long duration (160-180 days), photosensitivity, tall plant height (130-150 cms), susceptible to lodging and lower grain yield. After establishment of Rice Research Station at Buchi Reddy Palem (BCP) in the year 1937, efforts for improvement of these rice varieties were made and several improved versions were developed through pureline selection with yield potential of 2.8 to 3.7 t/ha and tolerant to blast and drought. Later on, through hybridization with high yielding plant type varieties following pedigree methods, a series of new varieties were developed with yield improvement upto 5.5 to 6.6 t/ha , which became very popular amongst the farming community (Ramesh Babu *et al.,* 2016).

With the advent of very high yielding rice varieties and hybrids, currently it is felt necessary that new high yielding varieties needs to be developed keeping the traditional quality features of Molakolukulu rices. In this context, it is necessary to undertake genetic investigation, characterisation and character association studies in

Molakolukulu rice varieties for their further improvement. Therefore, present study was conducted in order to investigate the genetic parameters, characterisation and character association in 25 Molakolukulu rice varieties.

MATERIALS AND METHODS

The present experiment was carried out during *kharif*, 2017 at Agricultural Research Station, Nellore, Andhra Pradesh, India which is located at an altitude of 20 m above MSL, latitude of 14^0, 54' N and longitude of 79^0, 59' E. The experimental material consisted of 24 long duration Molakolukulu rice genotypes obtained from Agricultural Research Station, Nellore, Andhra Pradesh (**Table 1**). MTU 7029 was used as a check to compare the 24 Molakolukulu genotypes. The material was raised in two replications using randomized block design with a spacing of 20 x 15cm and a plot size of $5m^2$. All the standard crop production and protection strategies were followed to raise a healthy crop. A total of 12 grain yield attributes and 12 quality traits (**Table.5.1 and 2**) were studied. Observations were recorded on ten randomly selected plants per treatment per replication and were used for statistical analysis. However, days to 50 % flowering, kernel length and kernel breadth were recorded per plot basis. Broad sense heritability (h^2) was calculated as per the procedure suggested by Lush (1940) and genetic advance as per cent of mean (GAM) was estimated based on the formula proposed by Johnson *et al.* (1955). Correlation coefficients and path coefficients were estimated as per the methods suggested by Pearson (1897 and Dewey and Lu (1959) respectively.

RESULTS AND DISCUSSION

Molakolukulu rice is the traditional group of rice grown in southern zone of Andhra Pradesh, specifically cultivated in the Nellore district. The group of rice varieties are known for their preferred quality of cooked rice although the grain type is medium in nature. It is preferred for the keeping quality of cooked rice. Even after 24 hours of cooking. The cooked rice does not spoil. Hence, the persons working under the sun prefer to eat this rice along with curd or butter milk in the next day morning. Recently, due to the changed climatic scenario, rainfall pattern and cropping system the area under molakolukulu is gradually declining. But these genotypes perform well under natural and organic farming conditions. Hence, preference of consumers has been regain slowly in recent years.

The analysis of variance indicated significant differences among the 25 genotypes for all the characters studied except for grain yield. The phenotypic coefficient of variation was higher than the genotypic coefficient of variation indicating the influence of environment in the expression of the traits. The estimates of PCV and GCV were high for the characters gel consistency, alkali spreading value, zinc content and oil content indicating considerable genetic variability for these traits in the experimental material. High PCV and moderate GCV were observed for filled grains per panicle, water uptake and iron content. Moderate PCV and GCV were observed for plant height, flag leaf length, productive tillers per panicle and protein content. Low PCV and GCV were observed for days to 50 % flowering, test weight, kernel length, kernel breadth, kernel L/B ratio, hulling%, milling%, head rice recovery, kernel elongation ratio, volume expansion ratio, gel consistency and amylose content indicating low variability for these characters in the present experimental material and therefore little scope for improvement of these traits (**Table 2**).

The classification of kernel size and shape of rice is as follows:

Size classification		Shape classification	
Extra long	>7.5mm	Slender	L?B ratio >3
Long	6.6-7.5mm	Medium	2.1-3
Medium	5.5-6.6mm	Bold	1.1-2
Short	<5.5mm	Round	<1.1

(As per standard evaluation system of Rice, IRRI)

An insight into the *per se* performances of genotypes indicated that BCP-4 (130), NLR 20128 (130), BCP-2 (131), BCP-3 (131) and Bulk H/9 (132) were of relatively most long duration types. The entries with lower plant height were MTU 7029 (71cm), NLR 3337 (93cm), NLR 3186 (101cm) and NLR 9674 (103cm). NLR 3115 had showed high mean value in desirable direction with characters like high flag leaf breadth, kernel L/B ratio, milling % and gel consistency. BULK-H/9 showed more number of productive tillers per plant along with highesr number of days to 50 percent flowering and high zinc content. NLR 28600 showed high iron content, high protein content and high head rice recovery. Whereas, highest number of filled grains per panicle was recorded in NLR 33641, test weight in BCP-5, oil content in NLR 33891, and panicle length in BCP-4. High kernel breadth, volume expansion ratio and kernel elongation ratio were recorded in NLR 9672-96. Highest water uptake and volume expansion ratio were recorded in NLR 9674. High flag leaf length and alkali spreading value were recorded by NLR 27999 and BCP-3 respectively. Highest grain yield was recorded in NLR 33365. The identified genotypes best for their per se performance with respect to various traits, would have significant implication in the selection of parents for use in further breeding programme.

Table 1. Twenty five rice genotypes with pedigree and source

S. No.	Genotype	Pedigree	Year of release	Special Characters
1	BCP-1	Pure line selection from Sanna molakolukulu	1948	Matures in 190 days. Grows to a height of 134.5 cm. Yields 2.83 t/ha. Tolerant to blast
2	BCP-2	Pure line selection from Budda/ Potti molakolukulu	1948	Matures in 185 days. Grows to a height of 143.2 cm. Yields 2.83 t/ha. Tolerant to blast. Drought resistant
3	BCP-3	Pure line selection from Atragada	1950	Matures in 160 days. Grows to a height of 147.3 cm. Yields 3.61 t/ha.
4	BCP-4	Pure line selection from Pishanam	1950	Matures in 180 days. Grows to a height of 138.2 cm. Yields 2.72 t/ha. Tolerant to blast. Drought resistant.
5	BCP-5	Pure line selection from Sannavadlu	1951	Matures in 190 days. Grows to a height of 145.5 cm. Yields 2.60 t/ha. Tolerant to blast. Drought resistant
6	BCP-6	Pure line selection from Molakolukulu	1965	Matures in 180 days. Grows to a height of 132.5 cm. Yields 3.7 t/ha. Tolerant to blast. Drought resistant
7	BULK H/9	Pure line selection from Molakolukulu	1965	Matures in 180 days. Grows to a height of 149.5 cm. Yields 3.7 t/ha. Tolerant to blast. Drought resistant
8	POMBAL	LANDRACE	-	-
9	NLR 9672 (Kotha molakolukulu)	BULK H9/Millek kunning	1977	First cross derivative with blast resistance, matures in 150-160 days
10	NLR 9674 (Kotha molakolukulu)	BULK H9/Millek kunning	1977	First cross derivative with blast resistance, matures in 160-170 days
11	NLR 9672-96 (Pinakini)	BULK H9/Millek kunning	1987	Long duration (160 days) Molakolukulu rice with tolerance to blast.
12	NLR 27999 (Tikkana)	RP 31-49-2/BCP 2	1988	Long duration (165 days) Molakolukulu rice with tolerance to blast.
13	NLR 28600 (Simhapuri)	RP -32/BULK h9	1991	Long duration (165 days) Molakolukulu rice with tolerance to blast.
14	NLR 28523 (Sriranga)	RP -32/Mahsuri	1991	Long duration (165 days) Molakolukulu rice with tolerance to blast. Fine grain with good cooking quality
15	NLR 33892 (Parthiva)	Tikkana/MTU 4870	2006	Long duration rice (155 days) with Blast resistance and BPH tolerance.
16	NLR 20084	NLR 33057/NLR 28600	PRC	Matures in 150-155 days. Suitable for *kharif* season, resistant to blast.
17	NLR 33365 (Penna)	NLR 9672/IR 36	1996	Long duration rice (165 days) with Blast resistance
18	NLR 33641 (Vedagiri)	NLR 9672-96/ET 7230	1999	Long duration (155 days) rice with Blast resistance
19	NLR 33891	Pinakini/MTU 4870	PRC	Matures in 155 days. Resistant to blast.
20	NLR 3328	NLR 33892/BPT 5204	PRC	Matures in 150 days. Short bold grain, tolerant to blast.
21	NLR 33810	NLR 9672-96/MTU 4870	PRC	Matures in 150 days.
22	NLR 3115	BPT/NLR 33641	PRC	Matures in 155 days, blast resistant, medium slender grains and non-lodging.
23	NLR 3337	BPT/NLR 145/NLR 33654/BPT 5204	PRC	Matures in 150-155 days, golden brown huskand tolerant to blast.
24	NLR 20128	NLR 33892/BPT 5204	PRC	Matures in 155-160 days, golden brown husk and blast resistant.
25	MTU 7029 (Swarna)	Vasishta/Mahsuri	RARS, Maruteru.	High yielding, long duration (150 days), semi dwarf variety, resistant to BLB.

Table 2. Mean, variability, heritability and genetic advance as per cent of mean for yield and quality parameters in molakolukulu rice (*Oryza sativa* L.)

S. No.	Character	Mean	Range Lowest	Range Highest	GCV%	PCV%	Heritability (Broad Sense)	Genetic Advance as % of Mean at 5% level
1	Days to 50% Flowering	127.02	120.00	132.50	2.32	2.49	86.97	4.46
2	Plant Height (cm)	119.06	71.90	147.15	15.52	15.89	95.30	31.20
3	Panicle Length (cm)	24.67	19.32	29.95	8.16	9.65	71.50	14.21
4	Flag Leaf Length (cm)	35.07	22.19	46.32	15.04	15.82	90.30	29.44
5	Flag Leaf Breadth (cm)	1.34	1.10	1.62	8.32	10.79	59.44	13.21
6	Productive Tillers	13.48	9.00	19.00	10.84	15.75	47.39	15.38
7	Filled Grains	112.18	73.00	156.00	16.89	20.17	70.19	29.16
8	Test Weight (g)	20.35	16.26	23.55	7.99	8.81	82.30	14.93
9	Iron content (ppm)	9.96	5.40	13.15	17.77	21.87	66.04	29.75
10	Zinc content (ppm)	19.08	6.40	37.85	30.28	39.34	59.24	48.01
11	Oil content (%)	0.31	0.19	0.52	21.54	25.80	69.70	37.04
12	Protein content (%)	7.32	6.23	9.12	10.00	10.98	82.93	18.76
13	Grain Yield	30.18	24.80	37.20	7.45	13.26	31.55	8.62
14	Kernel Length (mm)	5.69	5.45	6.50	2.84	3.71	58.79	4.49
15	Kernel breadth (mm)	2.41	2.10	2.65	5.33	6.58	65.45	8.88
16	Kernel L/B Ratio	2.40	2.13	3.03	8.07	9.64	70.23	13.94
17	Hulling %	76.57	73.40	79.20	1.48	1.97	56.12	2.28
18	Milling %	68.86	62.40	73.20	4.46	5.40	68.24	7.60
19	Head Rice Recovery	58.91	51.25	68.30	8.08	8.52	89.88	15.78
20	Volume Expansion Ratio	3.65	2.80	4.07	7.90	9.78	65.16	13.13
21	Kernel Elongation Ratio	1.76	1.53	1.89	4.09	6.37	41.29	5.42
22	Gel Consistency	37.02	21.00	60.50	31.91	33.20	92.36	63.17
23	Alkali Spreading Value	2.32	1.00	3.50	22.60	30.83	53.75	34.14
24	Water Uptake	160.94	100.00	212.75	16.76	22.42	55.90	25.82
25	Amylose content	25.28	19.65	28.24	9.67	9.87	96.00	19.52

PCV = Phenotypic coefficient of variation GCV = Genotypic coefficient of variation

The estimates of heritability and genetic advance as per cent of means were high for the characters plant height, flag leaf length, filled grains per panicle, gel consistency, oil content and iron content, indicating the involvement of additive gene action in the inheritance of these traits. Hence simple selection would be rewarding. High heritability coupled with moderate genetic advance as per cent of mean was observed for panicle length, test weight, kernel L/B ratio, head rice recovery, protein content, volume expansion ratio and amylose content. Moderate heritability coupled with high genetic advance as per cent of mean was observed for zinc content, alkali spreading value and water uptake indicating involvement of additive gene action in the inheritance of these traits. Moderate heritability coupled with moderate genetic advance as per cent of mean was observed for flag leaf breadth and productive tillers per plant indicating involvement of both additive and non additive gene action in the inheritance of these traits thus simple selection may not be effective instead population improvement for these traits would be desirable.

Grain yield per plant was significantly and positively associated with filled grains per panicle (0.4667**) and flag leaf breadth (0.4852**) (**Table 3**). The number of filled grains per panicle, which is not only an index of the photosynthetic efficiency but also the source -sink relationship of the plant, lead to increased grain yield and can be considered as the important attributes for improvement of grain yield. These findings were in confirmation with Ajmera *et al.* (2017) for filled grains per panicle, Venkanna *et al.* (2014) for panicle length and productive tillers and Rani and Reddy (2010) for test weight.

Table 3.1 Phenotypic correlations among yield and yield attributing traits in molakolukulu rice (*Oryza sativa* L.)

Character	Days to 50% Flowering	Plant Height	Panicle Length	Flag Leaf Length	Flag Leaf Breadth	Productive Tillers	Filled Grains	Test Weight	Iron	Zinc	Oil Content	Protein content	Grain yield
Days to 50% Flowering	1.0000	0.5620**	0.1676	0.1731	-0.2040	0.2183	-0.0311	0.0156	-0.0098	0.0981	-0.1072	0.0361	-0.0056
Plant Height		1.0000	0.5046**	0.4708**	-0.1624	0.2943*	-0.3113*	0.4404**	0.1305	0.0126	0.0229	-0.0157	0.1260
Panicle Length			1.0000	0.4559**	0.3231*	-0.1303	-0.2505	0.5357**	0.1321	-0.0137	0.1183	-0.0333	0.0624
Flag Leaf Length				1.0000	0.1083	0.0532	-0.4359**	0.4474**	0.0494	-0.0110	0.1706	0.2999*	-0.0563
Flag Leaf Breadth					1.0000	-0.3556*	0.2900*	0.1468	-0.0264	-0.1782	0.1778	-0.0687	0.3237*
Productive Tillers						1.0000	-0.3414*	-0.1913	0.1279	0.3052*	-0.0903	0.0297	0.0205
Filled Grains							1.0000	-0.2821*	-0.1412	-0.2742	0.3422*	-0.0004	0.4667**
Test Weight								1.0000	0.0540	-0.0985	-0.0395	-0.0190	0.0971
Iron									1.0000	0.1046	0.0069	0.3219*	0.0496
Zinc										1.0000	-0.2702	0.0906	-0.2323
Oil Content											1.0000	0.1799	0.1888
Protein content												1.0000	-0.1795

** Significant at 1% level   * Significant at 5% level

Table 3.2 Phenotypic correlations among amylose content and quality traits in molakolukulu rice (*Oryza sativa* L.)

Character	Kernel Length	Kernel Breadth	Kernel L/B Ratio	Hulling %	Milling %	Head Rice Recovery	Volume Expansion Ratio	Kernel Elongation Ratio	Gel Consistency	Alkali Spreading Value	Water Uptake	Amylose Content
Kernel Length	1.0000	-0.0012	0.3162*	0.3064*	0.1579	0.0723	-0.0510	-0.1546	0.1503	-0.0022	0.0748	-0.0487
Kernel Breadth		1.0000	-0.8580**	-0.1368	-0.2095	0.0678	0.0526	0.1797	-0.3792*	-0.0793	0.2184	-0.0192
Kernel L/B ratio			1.0000	0.2974*	0.2259	0.0091	-0.0128	-0.3047*	0.4769**	0.0477	-0.0940	-0.0556
Hulling %				1.0000	0.6753**	0.3922**	0.2135	0.1888	0.2561	-0.2782*	0.1587	0.1419
Milling %					1.0000	0.6003**	-0.0951	0.1443	0.3144*	-0.1869	-0.2169	0.0640
Head Rice Recovery						1.0000	0.0386	0.0384	-0.0053	-0.0612	-0.0772	0.1139
Volume Expansion Ratio							1.0000	0.4004**	-0.1537	-0.1853	0.6552**	-0.0722
Kernel Elongation Ratio								1.0000	-0.0618	-0.3473*	0.3113**	0.0140
Gel Consistency									1.0000	-0.2137	-0.2584	-0.1445
Alkali Spreading Value										1.0000	0.0426	0.3551*
Water Uptake											1.0000	0.0152
Amylose content												1.0000

** Significant at 1% level   * Significant at 5% level

In the present investigation days to 50 % flowering had significant positive correlation with plant height (0.5620**) which is in accordance with earlier findings of Edukondalu *et al.* (2017). The correlation of plant height with panicle length (0.5046**), flag leaf length (0.4708**), productive tillers (0.2943*) and test weight (0.4404**) was significant positive. These results were in agreement with the earlier findings of Singh *et al.* (2018) for panicle length, Srijan *et al.* (2016) for flag leaf length, Hefena *et al.* (2016) for productive tillers and Prasanna Kumari *et al.* (2020) and David *et al*. (2022) for test weight. On observation of these results, it may be concluded that genotypes which recorded more plant height in the present study manifested more panicle length and bold grains & high protein content also.

Panicle length, an important yield contributing character showed positive significant association with flag leaf length (0.4559**), flag leaf breadth (0.3231*) and test weight (0.5357**). Sadeghi (2011) and Sravan *et al.* (2012) reported similar results for this trait. Increased flag leaf area increased the photosynthetic area which might result in increased panicle length which in turn produced more number of grains thus increased the grain yield.

The flag leaf length showed positive significant association with test weight (0.4474**) and protein content (0.2999*) as reported earlier by Rukminidevi *et al.* (2017). As majority of the genotypes studied were having lengthy flag leaf (>30) which tend to droop causing mutual shading and not intercept more sunlight resulted in negative association and finally low grin yield.

The flag leaf breath had positive significant association with filled grains (0.2900*) as reported earlier by Rukminidevi *et al.* (2017). The increase in flag leaf breadth leads to increase in photosynthetic area which increases the number of filled grains per panicle which ultimately leads to increase in grain yield per plant.

Productive tillers per plant had showed positive significant association with zinc content (0.3052*). Which was in accordance with Ajmera *et al.* (2017). The trait showed negative significant association with filled grains per panicle (-0.3414*) indicating that the need to adopt the strategy of increasing sink size per panicle by selecting genotype with more number of grains per panicle instead of more number of tillers while developing new varieties.
Number of filled grains per panicle is one of the most important yield contributing trait, and its association was positive significant with oil content (0.3422*). Its association was negative significant with test weight (-0.2821*). These results were in accordance to the findings of Edukondalu *et al.* (2017) for test weight.

Iron content showed positive significant association with protein content (0.3219*) indicating that there is a possibility of improvement of these two traits simultaneously. The oil content of rice is low (0.5-1%) and most of it is removed in the process of milling and is also known to influence viscoelastic properties by forming inclusion complexes with the helical structure of amylose.

Amylose content is the one of the most important trait which determines the cooking quality of rice. Intermediate amylose content (20-25) is the preferable character for most of the areas where rice is consumed as staple food. Amylose content showed significant positive correlation with alkali spreading value (0.3551*) which was supported by Chowdhury *et al.* (2016a) indicated that higher amylose content may lead to the recovery of genotypes with soft gel consistency.

Among the quality traits, kernel length had positive significant association with kernel L/B ratio (0.3162*) and hulling% (0.3064*) as reported earlier by Madhubabu *et al.* (2017). Kernel breadth showed negative significant association with kernel L/B ratio (-0.8580**) and gel consistency (-0.3792*) which was in accordance with the earlier findings of Santhipriya *et al.* (2017) and Tejaswini *et al.* (2018) for kernel L/B ratio. Kernel L/B ratio got significant positive association with hulling% (0.2974*) and gel consistency (0.4796**) which was in agreement with the findings of Nandan *et al.* (2010) for hulling% and Chamundeswari *et al.* (2014) for gel consistency. The trait showed significant negative association with kernel elongation ratio (-0.3047*) as reported earlier by Nandan *et al.* (2010).

A positive significant association was observed with milling % (0.6753**) and head rice recovery (0.3922**). Shivani *et al.* (2007) reported significant positive association of hulling% with milling % and head rice recovery. Hulling% showed negative significant association with alkali spreading value (-0.2782*). Milling% showed significant positive association with head rice recovery (0.6003**) and gel consistency (0.3144*) which was in accordance with the findings of Chowdhury *et al.* (2016) for head rice recovery and Madhubabu *et al.* (2017) for gel consistency.

Volume expansion ratio had significant positive association with kernel elongation ratio (0.4004**) and water uptake (0.6552**). Sreelakshmi (2018) got similar results for volume expansion with kernel elongation ratio in rice. If more is the kernel elongation, generally the expansion of rice will also increase. Kernel elongation ratio had positive significant association with water uptake (0.3113*). Which was in accordance with Madhu Babu *et al.* (2017). A significant negative association was observed between kernel elongation ratio and alkali spreading value (-0.3473*).

Critical analysis of the results of path analysis for grain yield revealed that positive direct effect of plant height, flag leaf length, flag leaf breadth, productive tillers per plant, filled grains per panicle, test weight and iron content was

Table 4.1 Direct and indirect effects (phenotypic) of different yield attributing traits on grain yield per plant in molakolukulu rice (*Oryza sativa* L.)

Character	Days to 50% Flowering	Plant Height	Panicle Length	Flag Leaf Length	Flag Leaf Breadth	Productive Tillers	Filled Grains	Test Weight	Iron	Zinc	Oil	Protein	Grain yield
Days to 50% Flowering	**-0.1532**	-0.0861	-0.0257	-0.0265	0.0313	-0.0334	0.0048	-0.0024	0.0015	-0.0150	0.0164	-0.0055	-0.0056
Plant Height	0.1272	**0.2263**	0.1142	0.1065	-0.0367	0.0666	-0.0704	0.0996	0.0295	0.0029	0.0052	-0.0036	0.1260
Panicle Length	-0.0089	-0.0268	**-0.0531**	-0.0242	-0.0171	0.0069	0.0133	-0.0284	-0.0070	0.0007	-0.0063	0.0018	0.0624
Flag Leaf Length	0.0290	0.0788	0.0763	**0.1673**	0.0181	0.0089	-0.0729	0.0749	0.0083	-0.0018	0.0285	0.0502	-0.0563
Flag Leaf Breadth	-0.0403	-0.0321	0.0638	0.0214	**0.1975**	-0.0702	0.0573	0.0290	-0.0052	-0.0352	0.0351	-0.0136	0.3237*
Productive Tillers	0.0707	0.0953	-0.0422	0.0172	-0.1152	**0.3240**	-0.1106	-0.0620	0.0414	0.0989	-0.0293	0.0096	0.0205
Filled Grains	-0.0223	-0.2236	-0.1800	-0.3131	0.2083	-0.2452	**0.7184**	-0.2026	-0.1015	-0.1970	0.2458	-0.0003	0.4667**
Test Weight	0.0026	0.0722	0.0878	0.0734	0.0241	-0.0314	-0.0462	**0.1639**	0.0088	-0.0161	-0.0065	-0.0031	0.0971
Iron	-0.0016	0.0212	0.0214	0.0080	-0.0043	0.0207	-0.0229	0.0088	**0.1622**	0.0170	0.0011	0.0522	0.0496
Zinc	-0.0085	-0.0011	0.0012	0.0009	0.0154	-0.0263	0.0236	0.0085	-0.0090	**-0.0861**	0.0233	-0.0078	-0.2323
Oil	0.0086	-0.0018	-0.0095	-0.0137	-0.0143	0.0073	-0.0276	0.0032	-0.0006	0.0218	**-0.0806**	-0.0145	0.1888
Protein	-0.0088	0.0038	0.0082	-0.0735	0.0168	-0.0073	0.0001	0.0047	-0.0789	-0.0222	-0.0441	**-0.2449**	-0.1795

R SQUARE = 0.4952 **RESIDUAL EFFECT = 0.7105**

Table 4.2 Direct and indirect effects (phenotypic) of different quality traits with amylose content in molakolukulu rice (*Oryza sativa* L.)

Character	Kernel Length	Kernel Breadth	Kernel L/B Ratio	Hulling %	Milling %	Head Rice Recovery	Volume Expansion Ratio	Kernel Elongation Ratio	Gel Consistency	Alkali Spreading Value	Water Uptake	Amylose Content
Kernel Length	**-0.0124**	0.0000	-0.0039	-0.0038	-0.0020	-0.0009	0.0006	0.0019	-0.0019	0.0000	-0.0009	-0.0487
Kernel Breadth	0.0005	**-0.3750**	0.3217	0.0513	0.0786	-0.0254	-0.0197	-0.0674	0.1422	0.0297	-0.0819	-0.0192
Kernel L/B Ratio	-0.1374	0.3729	**-0.4346**	-0.1293	-0.0982	-0.0039	0.0056	0.1324	-0.2073	-0.0207	0.0409	-0.0556
Hulling %	0.1592	-0.0711	0.1545	**0.5195**	0.3508	0.2037	0.1109	0.0981	0.1330	-0.1445	0.0824	0.1419
Milling %	-0.0455	0.0603	-0.0651	-0.1945	**-0.2880**	-0.1729	0.0274	-0.0416	-0.0905	0.0538	0.0625	0.0640
Head Rice Recovery	0.0099	0.0093	0.0012	0.0538	0.0824	**0.1373**	0.0053	0.0053	-0.0007	-0.0084	-0.0106	0.1139
Volume Expansion Ratio	0.0068	-0.0070	0.0017	-0.0286	0.0128	-0.0052	**-0.1341**	-0.0537	0.0206	0.0249	-0.0879	-0.0722
Kernel Elongation Ratio	-0.0169	0.0196	-0.0333	0.0206	0.0158	0.0042	0.0437	**0.1093**	-0.0068	-0.0379	0.0340	0.0140
Gel Consistency	-0.0077	0.0195	-0.0246	-0.0132	-0.0162	0.0003	0.0079	0.0032	**-0.0515**	0.0110	0.0133	-0.1445
Alkali Spreading Value	-0.0010	-0.0356	0.0214	-0.1251	-0.0840	-0.0275	-0.0833	-0.1562	-0.0961	**0.4496**	0.0192	0.3551*
Water Uptake	-0.0042	-0.0122	0.0052	-0.0088	0.0121	0.0043	-0.0365	-0.0173	0.0144	-0.0024	**-0.0557**	0.0152

R SQUARE = 0.2803 **RESIDUAL EFFECT = 0.8483**

observed indicating that they are the major contributing characters to grain yield in rice (**Table 4**). Conversely, negative direct effects were observed for days to 50% flowering, panicle length, zinc content, oil content and protein content.

In the present study, positive direct effect of grain yield was observed for filled grains per panicle (0.7184), productive tillers per plant (0.3240), plant height (0.2263), flag leaf breadth (0.1975), flag leaf length (0.1673), test weight (0.1639) and iron content (0.1622) in decreasing order of magnitude. Whereas, negative direct effects were observed for days to 50% flowering (-0.1532), panicle length (-0.0531), zinc content (-0.0861), oil content (-0.0806) and protein content (-0.2449). The findings of Singh *et al.* (2018) were in line with the present findings for filled grains, productive tillers, flag leaf breadth, flag leaf length, plant height and test weight. Whereas, Singh *et al.* (2018) reported negative direct effects for days to 50% flowering and panicle length and Sathisha *et al.* (2015) and Jayaprakash *et al*. (2017) for protein and zinc content.

A positive and direct effects for amylose content was observed with hulling%, head rice recovery, kernel elongation ratio and alkali spreading value. The negative direct effects were observed for kernel length, kernel breadth, kernel L/B ratio, milling%, volume expansion

Table 5.1. Mean performance of 25 genotypes for yield traits in molakolukulu rice (*Oryza sativa* L.)

No	Character	DFF	PH	PL	FLL	FLB	EBT	FG	TW	Iron	Zinc	Oil	Protein	GY
1	BCP-1	129.00	142.35	24.77	37.24	1.14	14.50	117.50	19.69	7.05	17.30	0.32	6.67	32.40
2	BCP-2	131.50	147.15	23.05	35.77	1.22	13.00	119.00	21.52	9.45	15.60	0.23	6.49	34.95
3	BCP-3	131.00	139.00	25.46	33.04	1.28	14.00	103.00	19.89	11.20	12.90	0.26	7.02	28.30
4	BCP-4	130.00	144.40	29.95	34.81	1.22	13.50	99.50	22.74	10.00	18.50	0.25	6.23	32.05
5	BCP-5	122.50	138.80	28.63	34.09	1.47	13.00	90.00	23.55	11.00	15.80	0.30	6.64	28.00
6	BCP-6	129.50	141.95	25.50	37.24	1.18	14.00	91.00	21.31	11.90	31.30	0.32	8.52	27.10
7	BULK-H/9	132.50	140.55	23.59	36.85	1.24	19.00	73.00	19.47	11.40	37.85	0.19	7.57	27.60
8	POMBAL	124.00	139.80	26.00	45.35	1.31	15.50	81.50	21.90	11.55	20.80	0.32	8.82	28.60
9	NLR 9672	126.00	109.40	23.14	38.58	1.39	14.00	101.00	20.22	10.45	12.00	0.28	7.27	30.00
10	NLR 9674	127.50	103.90	24.81	38.65	1.40	13.50	97.00	20.34	9.55	29.70	0.25	6.96	28.00
11	NLR 9672-96	125.00	114.90	23.23	39.11	1.37	12.50	100.00	20.19	5.40	19.00	0.28	6.24	24.80
12	NLR 27999	127.50	124.95	25.55	46.32	1.38	13.50	103.00	22.92	11.60	6.40	0.37	7.93	31.10
13	NLR 28600	129.00	119.25	25.77	40.30	1.28	11.00	129.00	19.92	13.15	15.50	0.42	9.12	27.70
14	NLR 28523	127.00	110.05	25.23	36.69	1.35	14.50	131.00	20.22	6.60	18.70	0.35	7.98	33.20
15	NLR 33892	125.00	106.05	23.82	32.92	1.26	14.00	111.00	17.87	7.60	13.90	0.32	6.89	30.10
16	NLR 20084	129.50	107.70	22.09	27.51	1.44	11.00	148.50	19.61	8.05	11.90	0.30	7.47	32.30
17	NLR 33365	125.00	111.05	25.68	34.85	1.49	13.50	101.00	22.28	11.45	17.40	0.33	6.69	37.20
18	NLR 33641	128.50	118.95	22.64	27.18	1.33	14.50	156.00	20.88	8.90	18.10	0.38	7.28	30.95
19	NLR 3186	125.00	101.85	26.68	37.93	1.50	9.00	102.00	22.41	7.85	22.50	0.26	7.67	27.80
20	NLR 33891	126.00	110.75	24.14	33.78	1.35	14.50	113.00	18.30	9.65	16.50	0.52	7.18	27.60
21	NLR 33810	124.50	110.10	23.14	32.22	1.54	12.50	138.50	19.35	9.90	17.60	0.31	8.18	32.80
22	NLR 3115	125.50	117.10	26.36	35.79	1.62	12.50	143.00	19.99	11.45	25.60	0.42	6.50	36.50
23	NLR 3337	124.00	93.30	22.09	27.86	1.28	15.00	131.50	16.26	13.05	22.60	0.25	7.15	32.40
24	NLR 20128	130.50	111.35	26.00	30.49	1.50	12.50	113.50	18.42	10.70	17.30	0.25	7.30	26.70
25	MTU 7029	120.00	71.90	19.32	22.19	1.10	12.50	111.00	19.56	10.05	22.30	0.22	7.13	26.40
	BPT 5204	**103.00**	**73.10**	**17.20**	**20.50**	**1.15**	**12.20**	**120.00**	**14.50**	**9.8**	**16.50**	**0.22**	**8.60**	**26.90**
	Mean	**127.02**	**119.06**	**24.67**	**35.07**	**1.34**	**13.48**	**112.18**	**20.35**	**9.96**	**19.08**	**0.31**	**7.32**	**30.18**
	C.V.	0.90	3.44	5.15	4.93	6.87	11.42	11.01	3.70	12.74	25.12	14.20	4.54	10.97
	S.E.	0.81	2.90	0.90	1.22	0.07	1.09	8.73	0.53	0.90	3.39	0.03	0.23	2.34
	C.D. 5%	2.36	8.46	2.62	3.57	0.19	3.18	25.49	1.56	2.62	9.89	0.09	0.69	6.83
	C.D. 1%	3.20	11.47	3.55	4.83	0.26	4.31	34.54	2.11	3.55	13.41	0.12	0.93	9.26
	Range Lowest	120.00	71.90	19.32	22.19	1.10	9.00	73.00	16.26	5.40	6.40	0.19	6.23	24.80
	Range Highest	132.50	147.15	29.95	46.32	1.62	19.00	156.00	23.55	13.15	37.85	0.52	9.12	37.20

Table 5.2. Mean performance of 25 genotypes for quality traits in molakolukulu rice (*Oryza sativa* L.)

No	Character	KL	KB	K L/B	Grain type	Hulling	Milling	HRR	VER	KER	GC	ASV	WU	Amylose
1	BCP-1	5.65	2.40	2.36	Medium	75.00	68.40	58.80	3.22	1.72	39.50	2.00	100.00	27.89
2	BCP-2	5.65	2.60	2.17	Medium	76.40	64.40	54.00	3.42	1.78	21.00	2.00	143.75	24.50
3	BCP-3	5.65	2.40	2.36	Medium	73.40	64.20	58.60	3.78	1.78	21.00	3.50	187.50	25.67
4	BCP-4	5.75	2.25	2.56	Medium	76.40	67.20	58.00	3.88	1.84	30.50	2.50	193.75	26.78
5	BCP-5	5.70	2.50	2.28	Medium	75.00	62.40	53.60	3.78	1.76	32.00	2.00	181.25	24.33
6	BCP-6	5.60	2.35	2.38	Medium	75.20	67.60	54.00	3.55	1.81	26.00	2.50	150.00	27.00
7	BULK-H/9	5.55	2.45	2.26	Medium	76.40	71.60	60.60	3.70	1.86	50.50	2.00	118.75	25.40
8	POMBAL	5.75	2.45	2.41	Medium	75.90	64.00	60.30	3.88	1.72	34.00	2.00	197.50	22.08
9	NLR 9672	5.65	2.40	2.36	Medium	75.60	68.00	53.60	3.85	1.84	37.50	2.00	144.00	19.65
10	NLR 9674	5.75	2.60	2.21	Medium	77.40	66.40	57.60	4.07	1.77	34.00	2.00	212.75	21.90
11	NLR 9672-96	5.65	2.65	2.13	Medium	76.40	68.40	56.80	4.07	1.89	35.50	1.00	212.50	22.69
12	NLR 27999	5.65	2.45	2.31	Medium	78.00	72.40	66.80	4.03	1.79	34.50	2.50	168.75	28.02
13	NLR 28600	5.75	2.60	2.22	Medium	78.00	72.80	68.30	3.85	1.87	52.00	2.00	187.50	27.13
14	NLR 28523	5.45	2.50	2.18	Medium	74.80	66.00	53.60	3.88	1.75	28.50	3.50	193.75	28.12
15	NLR 33892	5.55	2.35	2.36	Medium	78.00	70.40	60.30	3.95	1.87	22.00	2.50	175.00	26.65
16	NLR 20084	5.55	2.25	2.69	Medium	76.40	63.20	51.25	3.80	1.53	51.00	3.50	175.00	28.24
17	NLR 33365	5.65	2.65	2.13	Medium	77.20	70.40	68.20	3.53	1.73	22.50	2.00	137.50	27.39
18	NLR 33641	5.55	2.25	2.47	Medium	76.80	69.20	56.50	3.10	1.87	59.50	2.00	125.00	26.94
19	NLR 3186	6.50	2.35	2.77	Medium	79.20	72.80	58.20	3.68	1.68	44.50	2.50	175.00	27.03
20	NLR 33891	5.60	2.40	2.34	Medium	76.80	72.40	67.60	3.18	1.63	21.00	3.50	150.00	25.68
21	NLR 33810	5.65	2.20	2.57	Medium	76.00	72.00	60.20	3.38	1.68	44.50	2.00	131.25	21.94
22	NLR 3115	5.75	2.10	3.03	Medium	77.50	73.20	64.40	3.85	1.67	60.50	2.00	137.75	21.50
23	NLR 3337	5.65	2.25	2.60	Medium	78.40	71.60	57.50	3.70	1.70	31.50	1.50	175.00	27.25
24	NLR 20128	5.75	2.40	2.40	Medium	78.00	72.80	59.20	3.47	1.80	42.50	2.50	144.00	24.60
25	MTU 7029	5.75	2.45	2.37	Medium	76.00	69.60	54.80	2.80	1.57	49.50	2.50	106.25	23.58
	BPT 5204	**5.60**	**1.90**	**2.95**	**Medium**	**74.80**	**68.90**	**52.25**	**4.10**	**1.62**	**50.00**	**5.00**	**239.00**	**23.00**
	Mean	**5.69**	**2.41**	**2.40**		**76.57**	**68.86**	**58.91**	**3.65**	**1.76**	**37.02**	**2.32**	**160.94**	**25.28**
	C.V.	2.38	3.87	5.26		1.31	3.05	2.71	5.78	4.88	9.18	20.97	14.89	1.98
	S.E.	0.10	0.07	0.09		0.71	1.48	1.13	0.15	0.06	2.40	0.34	16.95	0.35
	C.D. 5%	0.28	0.19	0.26		2.06	4.33	3.30	0.44	0.18	7.01	1.00	49.46	1.03
	C.D. 1%	0.38	0.26	0.35		2.80	5.86	4.47	0.59	0.24	9.50	1.36	67.03	1.40
	Range Lowest	5.45	2.10	2.13		73.40	62.40	51.25	2.80	1.53	21.00	1.00	100.00	19.65
	Range Highest	6.50	2.65	3.03		79.20	73.20	68.30	4.07	1.89	60.50	3.50	212.75	28.24

ratio, gel consistency and water uptake. A negative non significant association along with negative direct effects was exerted by kernel length, kernel breadth, kernel L/B ratio, volume expansion ratio and gel consistency indicated that these characters cannot taken into consideration for selection of genotypes. The phenotypic residual effects for quantitative traits and for quality traits were 0.7105 and 0.8483 respectively. This indicated that apart from the traits included in the study, some more characters with significant effect on grain yield and quality are to be included in the study

Based on perse performance (**Table 5.1 and 5.2**) among the quality traits, NLR 3115 recorded high grain yield (>30g/plant) followed by high zinc content (>25ppm in polished rice), good oil percentage (>0.4%), and desirable amylose content (20-25). This may be due to the selection pressure for yield and other quality traits on the improvement of molakolukulu rice genotypes in due course of time. The variety NLR 28523 also possess good grain yield per plant, volume expansion ration and desirable amylose content for good quality rice. NLR 33810 also recorded good single plant yield followed by high protein content (>8%), Head rice recovery (>60%) and gel consistency in the desirable range (40-60).

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