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RESEARCH ARTICLE

Evaluation of yield and grain quality attributes in rice (*Oryza sativa* L.) genotypes

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Abstract

An experiment was conducted with 12 rice genotypes *viz*., Kaladhan, Sarjoo 52, NDR 101, NDR 103, NDR 107, NDR 111, NDR 117, NDR 119, KHP 102, KHP 106, KHP 107 and KHP-108 for evaluation of its grain quality and yield contributing traits during *kharif* season 2023. The grain of rice genotypes was evaluated for total starch, amylose, protein, iron, zinc and phytic acid content. The highest starch content was recorded in KHP 107 (79.31 g/100 g), while the lowest was in NDR 101 (74.49 g/100 g). High amylose content was noted in KHP 106 (24.36 g), NDR 103 (23.17) and NDR 119 (22.36). The maximum protein (10.54 g/100 g), iron (17.45 ppm) and zinc (27.44 ppm) were recorded in Kaladhan and lowest in NDR 101. Phytic acid had a negative and significant correlation with iron. Protein is positively and significantly associated with iron, zinc and amylose content. A positive and significant correlation was observed in days between flowering, grains/panicle and test weight with grain yield. The highest panicle length, number of grains/panicle, test weight and grain yield/plantwas noted in NDR 107 (32.50cm), KHP 107 (152.33), NDR 101 (27.93 g) and Sarjoo 52 (51.58 g/plant) respectively under normal environmental condition. The nutritional quality of Kaladhan and the grain yield potential of Sarjoo 52 can be used to develop rice genotypes for high grain yields with nutritional quality through molecular breeding approaches.

Keywords: genotypes; grain quality; phytic acid; rice; yield

Introduction

Rice (*Oryza sativa*) is consumed as a staple food by over half of the worlds' population. India ranks second in the world behind China and is one of the top rice producers, making up 22.5 % of global production (1). It is an important staple food consumed by 50 per cent of the countrys' population. Its production creates 3.5 billion person-days of employment and roughly 10 % of the agricultural GDP (2). India produced 137.83 mt of rice in 2023 - 2024 on an area of 47.82 mha (3). More than 15.83 million metric tons of rice were produced in Uttar Pradesh in 2023. With over 5.87 million hectares of land dedicated to rice farming, Uttar Pradesh is the second-largest rice - producing state in India. This represents around 13.5 % of Indias' total land area used for rice cultivation.

About 70 - 80 % carbohydrates, 6 - 12 % protein, 1.2-2.0 % mineral matter and a substantial amount of lipids and vitamins are all included in rice grains (4). Since starch makes up more than 80 % of the rice grain, it significantly impacts the quality of foods made with rice. Amylose and amylopectin glucan polymers make up starch and they are bundled together to create the insoluble, semi-crystalline starch granules (5). Plants produce at least two different types of starch. The plastids of photosynthetic organs are often home to transitory starch, which exhibits circadian turnover regulation with diurnal cycles (6). About 10 - 12 % of the endosperms' dry weight comprises protein, the second-largest component after starch (7). It provides 16 % of per capita protein needs and 23 % of the worlds' human/ capita energy. Although rice has a low protein content, it is possible to raise it. Water-soluble albumins, salt-soluble globulins, alcohol-soluble prolamines and alkali or acid-soluble glutelin are the main categories of rice seed storage proteins. Glutamine, which makes up about 60 % to 80 % of the total seed protein in rice grains, is the main protein in the starchy endosperm (8).

Since iron and zinc are obtained from common dietary sources and are influenced by comparable mechanisms in absorption and inhibition, they are frequently considered related in human nutrition. Anaemia, low birth weight, early childbirth, high maternal mortality risk and abnormal cognitive and motor development are just a few of the health issues that can result from a Fe deficiency (9). On the other hand, zinc deficiency causes hypogonadism, delayed wound healing, anorexia, skeletal abnormalities, immunological dysfunction and low height (10). Iron is a crucial element for producing the proteins myoglobin and haemoglobin, which are necessary for the bodys' blood to carry oxygen. Additionally, it is a vital part of the enzymes that support immune system function and energy metabolism (11).

In contrast, zinc serves as a cofactor for several enzymes and is involved in several biological processes, including gene expression, immunity, cell division and development. Consuming brown rice, which is more nutritious than white rice (milled rice), can help people overcome the issue of vitamin deficiencies (12). This research aims to identify a rice genotype with medium to high iron and zinc content, along with good yield potential, suitable for eastern Uttar Pradesh

Materials and Methods

An experiment was conducted in *Kharif* season 2023 with 12 rice genotypes/lines Kaladhan, Sarjoo 52, NDR 101, NDR 103, NDR 107, NDR 111, NDR 117, NDR 119, KHP 102, KHP 106, KHP 107, KHP 108 for evaluation of its grain quality traits, yield components and yield under normal environmental condition. Kaladhan is a local landrace with high iron and zinc content. Sarjoo 52 is a high-yielding prevalent rice genotype in eastern Uttar Pradesh. NDR 101, NDR 103, NDR 107, NDR 111, NDR 117, NDR 119, KHP 102, KHP 106, KHP 107 and KHP 108 rice lines were collected from Crop Research Station Masodha, Ayodhya and Department of Molecular Biology and Biotechnology, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, India. The field experiment used a factorial randomized block design under field conditions. A pre-sowing irrigation was done to obtain proper soil moisture for field preparation and seed germination. Twenty-five days old seedlings of rice genotypes were transplanted in plot size 2×2 m^2 with a spacing of 20 cm × 15 cm. The soil moisture was maintained as per the needs of the crop. Plants were kept weed-free by manual weeding up to the tillering stage of the crop. No disease management practices were adopted, as plants were disease-free till maturity. Days to 50 % flowering were recorded when 50 % of the plant population flowered. The adequate tillers number was recorded randomly for five selected plants and averaged on a per-plant basis at the reproductive stage. The test weight was recorded by counting 1000 seeds and weighed at a 12 % moisture level. Grain yield was recorded by randomly selecting five hills and the grain yield of each weighed at 12 % moisture level separately and averaged out to one as grain yield per plant. The grains of these genotypes were used to estimate the proteins, starch, phytic acid, zinc and iron content.

Estimation of total protein content

Samples of 0.50 g of ground powder of dehusked rice grain were thoroughly mixed with 0.2M phosphate buffer (pH-7.2) solution. The centrifuge samples were at 6000 rpm for 10 min and supernatants were collected in a fresh tube. Took 0.2 m supernatant in a tube and made final volume 1.0 mL with distilled water. The alkaline copper sulphate solution of 5 mL was added to each test tube, mixed thoroughly and kept for 10 min incubation. Diluted Folins' reagent of 0.5 mL was added to each tube, mixed thoroughly and incubated at room temperature for 30 min. The absorbance was recorded at 660 nm against blank. The rice samples' protein content was calculated using the standard curve procedure (13).

Estimation of starch content

The total starch content in grains of dehusked rice genotypes was recorded as described in the Association of Official Agricultural Chemists (AOAC) protocol (14). Starch was hydrolyzed in maltodextrins with the help of α-amylase enzyme. Maltodextrin is further hydrolyzed into D-glucose by amyloglucosidase. D-glucose was hydrolyzed into D-glucanate using glucose oxidase peroxidase enzyme. The pink colour was developed after the liberation of hydrogen peroxide. The absorbance of the pink colour aliquot was recorded at 520 nm against blank. The amount of starch in the sample was calculated by making a standard curve and expressed in a g /100 g sample.

Estimation of amylose content

The modified iodometric method was used to estimate amylose content in grains of dehusked rice genotypes (15). The rice grains were homogenized with sodium hydroxide and absolute ethanol and incubated for 15 min. The sample was diluted with 50 mL of distilled water. Then, iodine solution was added with acetic acid and kept at room temperature for 20 min for the appearance of a blue colour complex. Each samples' optical density (OD) was recorded at 620 nm against blank with the help of a Benchtop double-beam spectrophotometer (Zonotech, ZT-2201). The amylose content in OD was calculated by preparing a standard curve with rice amylose and the result showed a g/100 g sample basis.

Estimation of grain iron and zinc content

The flour of dehusked rice grain was digested in di-acid mixture in 9:1 of HNO3:HClO4 at 180˚C for 2 hrs on hot plate of REMI Model: 2MLH instrument for estimation of iron and zinc content (16). One gram of flour sample was put in 100 mL volumetric flask and added 10 mL acid mixture and mixed thoroughly. Then, the flasks were heated at high temperature until releasing NO_2 fumes completely ceased and the solution volume reduced to 2 to 3 mL and became colourless. The volume of solution was increased to 100 mL with deionized water in each flask of rice genotypes and finally filtered with Whatman paper. This solution sample was used to estimate iron and zinc content with the help of an Atomic Absorption Spectrophotometer (Zonotech, ZT-220).

Estimation of phytic acid content

The phytic acid content in the grain of dehusked rice genotypes was measured per the standard procedure (17). In a 100 g sample, 2 mL of 0.6 M HCl was mixed correctly in each tube. The samples were placed on a shaker at 120 rpm for 12 hrs. The samples were centrifuged at 10000 rpm for 10 min and the supernatant was collected in fresh tubes. The

Wade reagent of 1.25 mL was added in each tube separately and incubated for 20 min to develop a brown colour. The absorbance of each sample was recorded at 420 nm against blank with the help of a spectrophotometer. The phytic acid content was calculated by making a standard curve (5mg/ mL) using phytic acid dodecasodium salt hydrate in 0.65 M HCl (18).

Measurement of physical qualities of the grains

Rice grains were visualized and categorized based on size and form; however, more accurate measurements were needed to compare genotypes. It is classified based on seed shape, *i.e.* slender (≥3mm), medium (2.1mm-3mm) and bold (≤2.0mm) (19). Gain morphological characteristics such as grain length, width, Length-width ratio and grain shape of rice genotypes were measured by the Vernier Caliper (ESAW, 0.25mm-150mm). Accurate measurement and classification of particle size and form depend heavily on digital imaging and software tools (20).

Statistical analysis

The data were analyzed by using R software (Agricole package) (21), Indostat-9.2 (22) and XLSTAT Software. Descriptive statistics, frequency distribution and Pearsons' correlation coefficient analyses were performed using XLSTAT (23) software.

Results and Discussion

Yield and yield attributes traits

The rice genotypes had significant variability in growth, yield contributing traits and yield under normal environmental conditions (Table 1). The plant height (cm) at physiological maturity ranges from 83.53 to 140 cm. According to the current studys' findings, under typical climatic circumstances, genotype NDR107 had the highest plant height at maturity (140 cm), preceded by NDR 111 (136.83cm). In contrast, genotype KHP 102 had the lowest (83.53cm), followed by KHP 102 (89.73cm) and Kaladhan (89.73cm). Rice genotypes' characteristics, such as plant height, tillers number, days to flowering, panicle length, grains per panicle, test weight and yield, are controlled by genetics and environmental factors (Table 1). Significant diversity in agro-morphological traits was reported in rice genotypes (24, 25). Plant height is determined by growth, number of nodes and length (26). The number of tillers/ plant was recorded at the flowering stage and varied from 8.33 to 16. The maximum tiller number was noted in NDR 103 (16) and, followed by KHP 102 (14.2) while the minimum tiller number was observed in NDR 119 (8.33) followed by NDR 117 (8.67) and NDR 101(10.33). The genetic makeup of genotypes controls the variability in a number of tillers (27). Effective tillers are among the most essential yield components, as the final yield is mainly determined by the number of panicles bearing tillers per unit area (28).

The days to 50 % flowering in rice genotypes ranged from 90.33 - 106 days from date of sowing under normal environmental conditions. The maximum days to 50 % flowering was noted in NDR 107 and NDR111 (106 days) followed by NDR 103 (105 days) and Sarjoo 52 (100.67 days) while the minimum in Kaladhan (90.33 days) followed by KHP 102 (92.33 days) and KHP 108 (98.67 days). The days to 100 % flowering ranged from 96 -110.33 in rice genotypes. The maximum days to 100 % flowering was noted in NDR 107, while the minimum was in Kaladhan. Days to physiological maturity of rice genotypes varied from 124.33 to 143.34 days. The highest days to maturity was NDR 111 (143.33), followed by KHP 108 (140), NDR 103 and NDR 107 (136.67), while minimum Kaladhan (124.33 days), followed by NDR 117 (125 days), NDR 101 (126 days) and NDR 119 (130.33 days). Days to 50 % flowering is associated with the days to maturity and is a genotypic trait that varies among rice genotypes. Researchers have reported similar findings (29).

The panicle length of rice genotypes ranges from 21.5 to 32.5 cm. The maximum panicle length was noted in line NDR 107 (32.5 cm), followed by NDR 111 (29.17), NDR 103 (28.17) and KHP 106 (26.33), while the minimum panicle length was recorded in KHP 102 (21.50) followed by NDR 101 (22.33 cm), Sarjoo 52 (23.33 cm). The number of grains panicle^{-1} of rice genotypes varied from 84.33 to 152.33. The highest grain/panicle was recorded in KHP 107 (152.33), followed by Sarjoo 52 (149.33), KHP 108 (131.33 and NDR 111 (125), while minimum in KHP 102 (84.33), followed by NDR 101 (97.67), NDR 119 (110.67) and NDR 107 (112.33). The range of Test weight in rice genotypes was observed from 20.58 gm to 27.93 gm (Table 1). The highest test weight was noted in NDR101 (27.93), followed by NDR 119 (26.93), NDR 117 (26.53)

Table 1. Yield contributing traits and yield rice genotypes under normal sown conditions

Genotypes	PH (cm)	NTPP	FFP (50 %)	HFP(100 %)	DTM	PL (cm)	NOGPP	TW (g)	GY/P\ (g)
Kaladhan	89.73	12.00	90.33	96.00	124.33	23.57	133.00	22.96	27.70
Sarjoo 52	97.00	11.00	100.67	101.67	130.33	23.30	149.33	23.82	51.58
NDR 101	99.50	10.33	96.33	101.00	126.00	22.33	97.67	27.93	39.78
NDR 103	134.83	16.00	105.00	108.00	140.00	28.17	119.67	20.58	47.32
NDR 107	140.00	14.00	106.00	110.33	143.33	32.50	112.33	22.99	41.96
NDR 111	136.83	12.00	106.00	107.00	139.67	29.17	125.00	23.88	38.20
NDR 117	106.00	8.67	90.33	108.67	125.00	26.17	128.67	26.53	40.34
NDR 119	92.83	8.33	98.33	103.00	130.33	23.40	110.67	26.92	33.40
KHP 102	83.53	14.20	92.33	96.00	135.33	21.50	84.33	24.32	35.14
KHP 106	107.50	12.00	96.67	103.00	135.00	26.33	100.33	23.40	36.44
KHP 107	105.67	12.00	100.00	107.00	136.67	25.57	152.33	20.59	45.14
KHP 108	110.00	12.67	98.67	107.00	140.00	24.67	131.33	22.15	47.10
Mean	108.62	11.67	98.39	104.06	133.83	25.56	120.39	23.67	40.34
C.V. at 5 %	6.24	15.67	1.56	1.40	1.27	9.97	14.62	7.39	19.19
S.E.	3.91	1.06	0.89	0.84	0.98	1.47	10.16	1.15	2.21
C.D. 5 %	11.47	3.10	2.60	2.46	2.87	4.31	29.81	2.36	8.82

Where PH - Plant height, NTPP - Number of tillers per plant, FFP - Fifty percent flowering (50 %), HFP - Hundred percent flowering (100 %), DTM - Days to maturity PL- Panicle length, NOGPP - Number of grains per panicle, TW - Test weight, GY/P - Grain yield per plant.

and NDR 103 had the lowest (20.58gm), succeeded by KHP 107 (20.59), KHP 108 (22.15) and Kaladhan (22.96). Panicle length, number of filled grain/panicles and test weight varied among rice genotypes and were major contributors to the grain yield of rice genotypes (30).

Grain yield per plant was varied from 27.7gm to 51.58 gm. Maximum grain yield per plant was observed in genotypes Sarjoo 52(51.58 g) followed by NDR103 (47.32), KHP108 (47.1 g) and NDR 107 (41.96 g) and minimum grain yield per panicle in Kaladhan (27.7g) followed by NDR119 (33.4), KHP102 (35.14 g) NDR 101 (39.78 g) and KHP 106 (36.44 g). The grain yield/plant is associated with yield-contributing traits of rice genotypes. Effective tillers, filled grains/panicles and test weight are major yield-contributing traits and determinant yield of rice genotypes under existing environmental conditions (28).

The findings of the Pearsons' correlation study on different experimental rice genotypes are presented in Table 2. At the 5 % significant level, the strongest positive and significant association between 50 % flowering and 100 % flowering and grain yield per plant was found. At the genotypic level, the days to 50 % flowering had a strong positive association with plant height, the number of grains per panicle and the days to maturity. The days to maturity, number of grains per panicle and seed weight would all rise if the number of days to 50 % flowering was increased. The results of the correlation analysis showed a significant and positive correlation between plant height and the number of tillers per plant (r = 0.416), 50 % flowering (r = 0.813) and Days to maturity (r = 0.705). Researchers have reported similar findings (31). Grain yield per plant was significantly positively correlated with panicle length (r = 0.214), number of grains per panicle(r = 0.468) and number of productive tillers per plant (r = 0.284). Days to maturity showed a strong and significant correlation with the number of tillers per plant, 50 % flowering, 100 % flowering and plant height. We have found that there was a strong association between panicle length.

Table 2. Pearson correlation coefficients of 12 rice genotypes for yield and yield contributing traits (Prob > |r| under H0: Rho=0)

Traits	PH	NTPP	FFP	HFP	DM	PL	NOGPP	TW	GYP
PH	1.000	0.416	0.813	0.829	0.705	0.930	0.111	-0.396	-0.374
Prob		0.178	0.001	0.001	0.010	<.0001	0.732	0.203	0.231
NTPP		1.000	0.396	0.138	0.619	0.276	-0.032	-0.793	0.284
Prob			0.203	0.669	0.032	0.386	0.921	0.002	0.371
FFP			1.000	0.742	0.774	0.687	0.177	-0.413	0.530
Prob				0.006	0.003	0.014	0.583	0.182	0.077
HFP				1.000	0.587	0.759	0.392	-0.299	0.674
Prob					0.045	0.004	0.208	0.345	0.016
DM					1.000	0.647	-0.038	-0.634	0.410
Prob						0.023	0.907	0.027	0.185
PL						1.000	0.125	-0.389	0.214
Prob							0.698	0.211	0.504
NOGPP							1.000	-0.447	0.468
Prob								0.146	0.125
TW								1.000	0.375
Prob									0.229
GYP									1.000

Additionally, plant height showed a positive and statistically significant correlation with 50 % and 100 % flowering percentages. Grain yield was found to have a considerable positive correlation with days to maturity, number of grains per panicle and thousand seed weight at both genotypic and phenotypic levels (32). The perusal of data (Table 3 & Fig. 1 - 2) revealed that variation in plant height, tillers number, day to flowering, panicle length, grain/panicle and test weight grain yield significantly varied among rice genotypes due to variation in genetic setup. The analysis of distribution using skewness and kurtosis reveals the kind of gene action and the number of genes governing the features (33). Negative skewness is linked to duplicate (additive × additive) gene interactions, whereas positive skewness is connected to complementary gene action (34). Genes that govern qualities with a skewed distribution are typically dominant, regardless of whether they positively or negatively impact the trait. In the absence of gene interaction, kurtosis is less than zero or negative (Platykurtic); in the presence of gene interaction, it is more than zero or positive (Leptokurtic). Fewer genes are claimed to govern qualities with a leptokurtic distribution and many genes govern traits with a platykurtic distribution. Plant height, tiller number, panicle length, test weight, starch, protein, iron, zinc and phytic acid were positively skewed, indicating complementary gene action. Duplicate gene action was shown by the negative skewness of days to maturity, number of grains per panicle, grains yield per plant and amylose. Research findings agreed with previous studies on skewness and kurtosis distribution (35).

The physical characteristics of rice grain varied among rice genotypes (Table 4). The appearance of genotype Sarjoo 52, NDR 107, NDR117, NDR 119 and NDR108 reported medium shape. NDR107 appeared Bold and the remaining genotypes Kaladhan, NDR 101, NDR 111, KHP 102, KHP 106, KHP 107 observed slender shapes. The allure of rice is not just because of its flavour but also its hue. Its colour influences consumer preferences and perceptions of rice grain quality. It was observed that genotype Kaladhan

Table 3. Descriptive statistics for yield, yield component and quality traits in rice genotypes

Variable	Mean	Minimum	Maximum	Median	Std Error	Std Dev	Variance	Kurtosis	Skewness
PH (cm)	108.62	83.53	140.00	105.84	5.46	18.93	358.19	-0.73	0.68
NTPP	11.67	8.33	16.00	12.00	0.58	2.01	4.04	1.41	0.24
FP (50 %)	98.39	90.33	106.00	98.50	1.61	5.57	31.02	-1.01	-0.06
FP(100 %)	105.14	96.00	111.00	106.84	1.42	4.93	24.31	-0.69	-0.64
DM	133.83	124.33	143.33	135.17	1.88	6.51	42.38	-1.35	-0.22
PL	25.56	21.50	32.50	25.12	0.91	3.17	10.04	0.63	0.93
NOGPP	120.39	84.33	152.33	122.34	5.91	20.46	418.64	-0.51	-0.09
TW	23.84	20.58	27.93	23.61	0.67	2.32	5.40	-0.49	0.37
GYP	40.34	27.70	51.58	40.06	1.95	6.75	45.59	-0.26	-0.14
Starch	76.90	74.49	79.30	77.00	0.42	1.45	2.11	-0.83	0.05
Amylose	21.28	17.86	24.36	21.73	0.55	1.92	3.68	-0.08	-0.51
Protein	8.51	7.20	10.54	8.36	0.25	0.87	0.75	1.78	0.92
Iron	13.92	11.39	17.45	13.53	0.51	1.77	3.14	0.01	0.72
Zinc	24.24	21.63	27.44	24.00	0.42	1.46	2.12	1.53	0.52
Phytic	908.63	756.15	1108.07	914.50	34.42	119.25	14220.91	-0.96	0.30

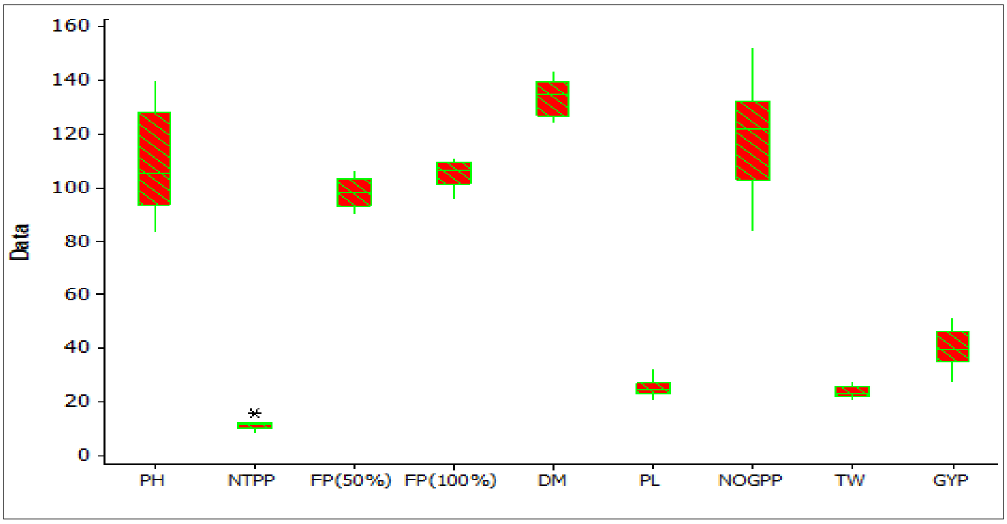

Fig. 1. Box plot depiction for yield and yield contributing traits of rice genotypes.

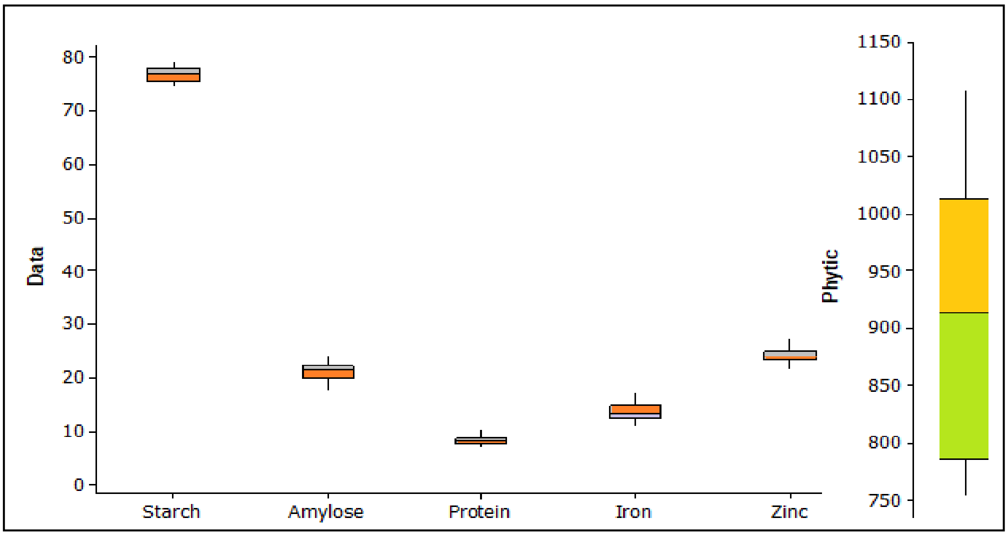

Fig. 2. Box plot depiction for grain quality traits of rice genotypes.

Table 4. Physical characteristics of grains of rice genotypes

Sr. No.	Genotypes	GL (mm)	GW (mm)	LWR	Seed Shape	Grain colour
1	Kaladhan	9.67	3.04	3.20	Slender	Blackish brown
2	Sarjoo 52	8.82	2.94	3.00	Medium	White
3	NDR 101	8.41	2.07	4.06	Slender	Whitish brown
4	NDR 103	9.41	2.81	3.71	Slender	Whitish brown
5	NDR 107	5.87	2.91	2.01	Bold	Whitish brown
6	NDR 111	9.37	2.52	3.75	slender	Whitish brown
7	NDR 117	7.64	2.84	2.71	Medium	Whitish brown
8	NDR 119	9.47	3.32	2.88	Medium	Whitish brown
9	KHP 102	8.54	2.29	3.8	Slender	White
10	KHP 106	8.72	2.29	3.87	Slender	White
11	KHP 107	8.49	2.6	3.33	Slender	White
12	KHP 108	8.57	3.04	2.81	Medium	White

Where GL= Grain length, GW = Grain width, LWR = Length width ratio.

had a Blackish Brown appearance and Sarjoo 52, as well as KHP series lines, had whitish appearance and all the lines of NDR reported the whitish brown color. Grain colour is quantitatively evaluated by colorimeters, which measure characteristics like hue angle, chroma and lightness (36).

Quality parameters

The rice genotypes had significant variability in protein, starch, amylose, iron, zinc and phytic acid content (Table 5). The total grain starch content of rice genotypes varied from 74.49 to 79.31 g/100g. Maximum starch content was recorded in KHP 107 (79.31g) preceded by NDR 117 (78.59g) and Minimum in NDR 101 (74.49g) is succeeded by NDR 111 (75.51g). Starch is the major grain component of rice genotypes and ranges from 71 to 83 %. It is an essential source of calorie for the rice - eating population. The amylose and amylopectin ratio determine the quality of rice grains. The amylose content of rice grain also determines the cooking quality and its structural patterns (37). High amylose content is directly proportional to firmness expansion and increases the water absorption properties, while low amylose increases glossiness, stickiness and tenderness. High amylose - containing rice genotypes are utilized in biscuits or crackers and low amylose content is used for noodles, puffs and bread in food and processing industries (38, 39).

Table 5. The starch, amylose, protein, iron, zinc and phytic acid content in grains of rice genotypes

Rice genotype	Starch (g/ 100 g)	Amylose (g/ 100 g)	Protein (g/100 g)	Iron (ppm)	Zinc (ppm)	Phytic acid (µg mL^{-1})
Kaladhan	75.51	22.34	10.54	17.45	27.44	780.00
Sarjoo 52	78.43	20.14	9.03	13.62	23.69	915.66
NDR 101	74.49	21.73	7.20	11.39	24.31	913.33
NDR 103	77.34	23.17	8.17	12.42	21.63	1035.56
NDR 107	76.6	20.18	9.00	15.12	23.53	916.54
NDR 111	75.51	21.73	7.91	13.44	24.64	1073.10
NDR 117	78.59	18.17	9.17	12.54	25.34	1108.07
NDR 119	75.63	22.36	8.12	14.57	25.41	805.86
KHP 102	77.38	21.10	8.7	16.48	23.65	763.43
KHP 106	76.45	24.36	8.40	14.44	24.7	756.15
KHP 107	79.30	22.16	8.31	12.58	23.67	888.25
KHP 108	77.47	17.86	7.62	13.04	22.89	947.52
Mean	**76.89**	**21.28**	**8.06**	**13.20**	**24.22**	**919.12**
C.V. at 5 %	**1.27**	**4.10**	**7.22**	**7.31**	**3.84**	**0.87**
S.E.	**0.56**	**0.84**	**0.33**	**0.55**	**0.53**	**4.62**
C.D. at 5 %	**2.25**	**1.83**	**1.34**	**2.22**	**2.14**	**18.43**

The grain protein content ranged from 7.2 to 10.54 g/100g in rice genotypes. The maximum protein content was reported in Kaladhan (10.54 g) preceded by NDR117 (9.17g) and the minimum in NDR 101 (7.2 g) succeeded by KHP 108 (7.62 g). Protein is considered as one of the important constituents of rice grain after starch content. It varies among rice genotypes and ranges from 5.50 to 12.50 % depending upon genetic and environmental factors (table 1). The rice genotypes that had >10 % protein content considered as high protein-containing rice genotypes. The similar finding for protein profiling of in Arunachal Pradesh land races ranges from 6.2 to 10.20 % (40). Protein content of Chhattisgarh rice land has a mean value of 6.63 % (41). while the protein content of Indian rice landrace mean value is 8.1 % from Hyderabad (42). The mean value of protein content of diverse Indian landraces is very low, 6.63 %. (43). The high protein content affects the properties of starch and restrains the expansion of rice grain and its' textured during cooking. High protein content also reduces the glycemic index by coating the starch granules and the enzyme action on starch granules (44).

The grain iron content varied in 12 rice genotypes, ranges from 11.39 to 17.45 ppm (Table 5). The maximum Iron content was recorded in Kaladhan (17.45), preceded by KHP 102 (16.48 ppm) and minimum in NDR 101 (11.39), succeeded by NDR 103 (12.42 ppm). The range of zinc content varied from 21.63 to 27.44 ppm. The maximum zinc content was observed in Kaladhan (27.44 ppm), preceded by NDR 119 (25.42 ppm) and Minimum in NDR 103 (21.63), succeeded by KHP 108 (22.89). The iron and zinc content vary due to genetic and edaphic factor (45). Brown/ red rice genotypes generally have higher iron and zinc content than polished rice. This research experiment also found that the genotype Kaladhan had high levels of iron and zinc. It also established a foundation for nutritional molecular breeding and improved biochemical research concerning manipulating protein, starch and phytic acid concentrations in high-yielding rice genotypes (46).

The phytic acid content varied from 756.15 to 1108.07 µg/mL. The maximum phytic acid content found in NDR 117 (1108.07 µg), preceded by NDR 111 (1073.1 µg) and the minimum in KHP 106 (756.15 µg). There is variability in phytic acid content in grains of rice genotypes (Table 5). Though the phytic acid is major source of phosphorus in rice grain but acts as antinutrient agent, particularly cationic nutrient (47). Phytic acid reduces the absorption and zinc in human body due to its chelating mechanism for active cation. High PA content also affects the starch hydrolysis and digestion lower the glycemic index (48). Therefore, rice genotypes with low phytic acid are more likely to accumulate more bioavailable iron and zinc (49).

Protein and amylose content showed a strong and positive correlation. According to correlation, amylose has the greatest impact on the starch-protein interactions that affect the quality of rice meals, followed by amylopectin and protein (50). In general, high genotypic correlations relative to their phenotypic equivalents (table 6) suggested a substantial intrinsic link between the traits, which may result from environmental factors that change (51). However, a negative and insignificant correlation existed between phytic acid and zinc, protein and amylose. Similar results were found, which indicated a favourable association between grain iron and zinc concentration (52). A drop or an increase above a particular threshold value is undesirable. Hence, rices' phytic acid content is a two-edged sword. Iron was significantly and negatively correlated with phytic acid. Iron and phytic acid had a substantial and negative relationship. According to this considerable association, a rise in amylose is linked to an increase. A significant decrease in the phytic acid content affects the rice plants' expected growth, development and agronomic performance. To maximize the nutritional value of rice, the phytic acid content must be optimally minimized because it reduces the bioavailability of mineral micronutrients such as iron and zinc (53).

Table 6. Pearson correlation coefficients of 12 rice genotypes for grain quality traits (Prob > |r| under H0: Rho=0)

Traits	Starch	Amylose	Protein	Iron	Zinc	Phytic
Starch	1.000	-0.383	0.179	-0.191	-0.396	0.232
Prob		0.219	0.579	0.553	0.203	0.468
Amylose		1.000	-0.025	0.175	0.116	-0.462
Prob			0.938	0.587	0.720	0.130
Protein			1.000	0.710	0.564	-0.238
Prob				0.010	0.056	0.456
Iron				1.000	0.496	-0.657
Prob					0.101	0.020
Zinc					1.000	-0.321
Prob						0.310
Phytic						1.000

Conclusion

The rice genotypes had significant variations in grain yield, contributing traits under normal environmental conditions. The grain yield ranges from 27.70 to 51.58 g/plant. High grain yield was recorded in Sarjoo 52, NDR 103 and KHP 108. The grain yield per plant positively correlated with productive tillers, grain per panicle and test weight. The quality traits like protein, starch, amylose, zinc, iron and phytic acid content varied among rice genotypes' grains. The zinc and iron content were negatively correlated with starch and phytic acid content. Kaladhan, NDR 107, KHP 102, KHP 106 had high protein, iron, zinc and low phytic content. NDR107 had a moderate yield with high iron content and NDR117 genotype was appeared with a moderate yield and high zinc content. These genotypes can be further used for the development of high-yielding rice genotypes with medium to high nutritional quality through physio-molecular breeding approaches.

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Authors' contributions

VK performed experimental work and wrote the research article. SP gave the concept, designed the experiment and communicated the manuscript. PS, RK and MK helped conduct the experiment and collect the literature. BB analysed the data, and AK helped in writing the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests

Ethical issues: None

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