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Research Article

Nutritional quality in rice grain and their relations to grain morphological traits

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ABSTRACT

Cereal grains are mainly considered by consumers due to their effect on health and because of their antioxidant capacity, phenolic content and other phytochemicals. For this purpose, an experiment was conducted to evaluate of morphological and nutritional traits on 10 rice genotypes. Analysis of variance showed a significant difference among the genotypes for all traits. Onda, Gharib, Fajr and L2 genotypes had the highest ranks for nutritional quality. Also, the results showed that there existed a positive correlation between antioxidant capacity, phenolic content, soluble carbohydrate and Zn content, while there was the negative correlation between grain length and grain length to width ratio with the above traits. Thus, the nutritional quality could be indirectly selected based on grain length. PCA analysis resulted five components that determined 89.22% of the total variation, so that scatter plot based on the two first components, the genotypes of Onda, Fajr, Gharib and L2 which have smaller grain length, have better nutritional quality. Therefore, these genotypes can be used in breeding programs.

Key words: Rice, Antioxidant, Phenolic content, Fe and Zn content, principal component.

Introduction

Improvement of grain quality is the main aim of rice breeders, because it affects the commercial value of rice grains (Koutroubas et al, 2004). The most important quality components, common to all users, include appearance, cooking and processing quality and nutritional quality (Fitzgerald et al, 2009). Appearance quality is usually determined by grain shape including length, width and length-width ratio of grain (Tan et al, 2000). It has recently been shown that rice grain shape is simultaneously controlled by triploid endosperm genes, cytoplasmic and maternal genes and genotype × environment interaction (Shi et al, 2000). Nutritional quality of rice has received more attention in the developing countries where because of monotonous consumption of rice may face deficiencies of essential minerals and other nutritional compositions (Shen et al, 2009). Numerous studies have shown that the essential phytochemicals in fruits, vegetables and cereal grains, including rice, are significantly associated with reduced risk of developing chronic diseases such as type 2 diabetes, and some cancers (Liu, 2007; Yawadio et al, 2007). The diversity in some phytochemicals in rice bran layers has been characterized (Shen et al, 2009) such as phenolic, flavonoids and carotenoids, etc. The phenolic compounds are also known as antioxidants that, along with other phytochemicals, are mainly distributed in the bran layer of rice grain (Jin et al, 2009). Pigmented rice such as red and black rice has higher amounts of phytochemicals

(Goffman and Bergman, 2004). The color of rice grain is positively correlated to the total phenolic and antioxidant capacity (Shen et al, 2009). Humans require at least 49 nutrients for their normal growth and development which among these nutrients, mineral elements such as Fe and Zn play numerous roles due to their direct or indirect effect in human metabolism (Garcia-Oliviera et al, 2008). In fact, two billion people worldwide suffer from micronutrient deficiencies, particularly in vitamin A, Fe and Zn (World Health Organization, 2007).Therefore, research has been undertaken to increase the micronutrient content in rice. The International Rice Research Institute is expected to release Fe-rich rice by the year 2029 to reduce Fe deficiency anemia in needy countries (Lau et al, 2015).

Shao et al (2011) studied the contents of phenolic and flavonoids in rice genotypes with different grain size. The smaller grains had higher phenolic content, flavonoid content and antioxidant capacity than the medium and larger grains. The phenolic content had positive correlation with the flavonoid content and antioxidant capacity. The phenolic and flavonoid content had negative correlation with grain length, grain length to width ratio and 100-grain weight, but had no correlation with grain width. They suggested new rice varieties with high antioxidant levels which could be obtained by being bred for extremely small grain rice. Study on total phenolic, flavonoid contents and antioxidant capacity from collection of rice germplasms were done, and their relations to grain color, grain size and 100-grain weight were investigated. Significant positive correlations were found among the phenolic, flavonoid contents and antioxidant capacity. Flavonoid contents had positive correlation to grain length and length to width ratio, and had negative correlation to the 100-grain weight. These relationships may serve as indexes to indirectly select breeding lines with high phenolic, flavonoids and antioxidant capacity. The results of this study may provide new opportunities for rice breeder's for production of rice with enhanced nutritional quality (Shen et al, 2009). 318 rice lines were to assess for variation in grain quality and to investigate relationships with morpho-physiological traits. Brown rice grain length ranged from 4.3 to 8.5 mm, grain width from 1.9 to 3.6 mm and grain length-to-width ratio from 1.3 to 4.0. Grain length was negatively correlated with grain width, indicating that selection for long grains would result in a negative response of grain width. These lines could be used as parents for introducing desired traits to current Indica cultivars grown in Europe (Koutroubas et al, 2004). Additionally, the interrelations among grain quality traits found in this study may be useful to understand the relationship among grain quality components. The objective of present study was grain nutritional quality variation and to compare with morphological traits for introduction better rice genotypes.

Materials and methods

Rice materials

10 rice genotypes (Onda, Fajr, Gharib, L2, Sepidroud, Amol2, Tarom-anesh, Abjiboji, Tarom-sadri, and Musa-tarom) were cultivated in April of 2016 at Sari Agricultural Sciences and Natural Resources University, Iran in a randomized complete block design with three replications. After harvesting, being air-dried and stored at room temperature for three months, rice grains were evaluated.

Physical and morphological properties

The 11 properties studied in this study, such as flag leaf length and width (FLL, FLW, respectively) (cm), panicle length (PL) (cm), grain length and width (GL, GW, respectively) (mm, with a caliper with accuracy 0.001), grain length to width ratio (GL to W), number of filled and unfilled grains per panicle (NFGP, NUGP, respectively), and 100-grains weight (100 GW) (g), which according to the Standard Evaluation System (SES) for rice were measured (SES, 2013). From each plot, 9 plants were randomly selected and measured.

Nutritional quality

Extraction methanolic extract

Brown rice flours (0.5 g) of each sample were extracted with 10 ml of 80% methanol for 24 h at room temperature. The methanolic extracts were centrifuged for 15 min and the supernatants were pooled and stored at 4°C (Shao et al, 2011).

Total antioxidant capacity (TAC)

The total antioxidant capacity was determined by DPPH radical scavenging activity (Molyneux, 2004) with UV VIS Spectrophotometer. Essay and speed DPPH radical scavenging activity method were usually used to measure the amount of antioxidants in cereal grains and crust of plant compounds (Chen et al, 2013). First, standard DPPH (0.1 mM) solution prepared. Then, 1.9 ml standard DPPH solution was added to 0.1 ml of extracts and mixed. The mixture stayed for 30 min at dark and room temperature. The absorbance read at 517 nm. Results were expressed as percent of extract DPPH radical scavenging by below Equation:

$$\text{Inhibition (\%)} = [\frac{\text{Absorbance of control} - \text{Absorbance of sample}}{\text{Absorbance of control}}] \times 100$$

Total phenolic content (TPC)

The Folin-Ciocalteu colorimetric method was used to measure the total phenolic content (Bao et al, 2005). Briefly, 60 µl of the extractions were oxidized with 1 ml Folin-Ciocalteu reagent (diluted 1:10) and then reaction was neutralized with 1 ml of the saturated sodium carbonate (75 g/L). The absorbance of samples was measured at 760 nm with UV VIS Spectrophotometer, after incubation for 2 h at room temperature and dark. Quantification was done on the basis of the standard curve of gallic acid and results were expressed as mg of gallic acid equivalent (GAE) per 100 g of flour weight.

Total carotenoid content (TCC)

0.1 g of powdered rice grain mixed and homogenized with 2 ml 80% acetone solvent. Then, samples was centrifuge for 10,000 rpm for 15min. The supernatant were separated and reached in 2 ml with acetone solvent. The solution mixture was analyzed for carotenoid content by Spectrophotometer in absorbance 663.2, 646.8 and 470 nm (Lichtenthaler, 1987). Equations used for calculation are presented below (Sumanta et al, 2014). Results were expressed as µg/ml.

$$Ca = (12.25A_{663.2}) - (279A_{646.8})$$

$$Cb = (12.25A_{663.2}) - (5.1A_{646.8})$$

$$\text{Total Cartenoid} = (1000A_{470} - 1.82Ca - 85.02Cb)/198$$

Total soluble and insoluble carbohydrates (TSC, TIC)

This measurement was performed by phenol-sulfuric acid assay, which is based on acidic hydrolysis of soluble carbohydrate and the formation of furfural compound that forms a color complex with a phenol (Kochert, 1978). In 0.1 g of samples in the test tube, we added 10 ml of 80% ethanol and allowed to stand at refrigerator for one week to release soluble sugars. Supernatant was used to measure the amount of soluble carbohydrate and deposits which were used for insoluble carbohydrate. After one week, the volume of 1 ml of supernatant separated reached to 2 ml with distilled water. Then, we added 1 ml 5% phenol and 5 ml 98% sulfuric acid. For measuring insoluble carbohydrate, first the deposit of samples were dried and, then, weighted. Then, to samples into test tube, we added 10 ml distilled water and allowed to stand for 15 min in bain-marie (boiling water). Afterwards, samples were filtered and their volumes reached to 25 ml. Finally, 2 ml of this solution was added to 1 ml 5% phenol and 5 ml 98% sulfuric acid. The absorbance of samples was measured at 485 nm with UV VIS Spectrophotometer. Quantification was done on the basis of the standard curve of glucose and results were expressed as mg of glucose (Glu) per 100 g of flour weight.

Fe and Zn contents

Fe and Zn contents of rice grain were determined by digestion method with dry burning and combination with hydrochloric acid in atomic absorption spectrometer (Waling et al, 1989). First, 0.5 g of each sample weighted to reach the standard in electric furnace for 5 h at 550 °C and converted to ash, then the ash was digested in 2N hydrochloric acid and their volumes reached to 50 ml with distilled water. Results are presented in below equation and are expressed as milligrams Fe and Zn per kilogram (ppm) of flour rice.

$C = (a \times v \times d)/(m \times Dm)$ Where, C: element concentration in mg/kg (ppm), a: mg/L in test solution, v: final volume of solution in ml, d: dilution factor (if not diluted, d=1), m: sample weight in g, Dm: % dry matter of sample.

Statistical analysis

Statistical analysis such as analysis of variance (ANOVA) and means were performed using SAS 9.1. For ranking of genotypes according to mean traits was used from Arunachalam and Bandyopadhyay methods (Arunachalam and Bandyopadhyay, 1984). First, the rank of each genotype was determined based on the mean of each trait. The ranking in each trait was done with number of letters related to mean of the same trait. For example, if mean of trait had four letters from A to D, then, ranking of genotypes will be as follows: the letters A, B, C and D have rank 4, 3, 2 and 1. If a genotype has two letters, its rank will be average of the same two letters. Final, total rank of each genotype will be sum of its rank in different traits. Correlation analysis and principal component analysis of the results were performed in SPSS 16.

Result and Discussion

There was a wide variation among genotypes for all traits (Table 1). For traits such as GL ranged from 6.18 to 11.65 mm, GW from 2.09 to 3.29 mm and GL to W from 2.65 to 4.82. Mean values were 9.16 mm for GL, 2.55 mm for GW and 3.60 for GL to W. Selection for grain size and shape during the primary generations of a breeding program involved the determination of GL and GW. This process is time-consuming (Koutroubas et al, 2004). FLL ranged from 24 to 39 cm with mean value of 30.5 cm. FLW ranged from 1.03 to 1.73 cm with mean of 1.23 cm and PL ranged from 25.33 to 33.07 with a mean of 29.91 cm.

There was a wide range of variations in the TPC in rice grain (Table 1). TPC ranged from 33.82 to 49.29 mg GAE/100g, with mean of 40.21 mg GAE/100g. TCC in all rice genotypes ranged from 0.06 to 2.01 µl/ml with mean of 0.87 µl/ml. The TAC was measured using the DPPH assay. It was varied to a great extent, averaged 45%, ranging from 19 to 79% among the total rice genotypes. In the present study grain TSC and TIC ranged from 45.46 to 119.73 and 45.70 to 146.03 mg Glu/100g, with mean of 72.54 and 97.74 mg Glu/100g, respectively. The Fe ranged from 22.07 to 115.90 mg/Kg with mean of 76.09 mg/Kg and the Zn ranged from 19.66 to 48.42 mg/Kg with mean value of 33.41 mg/Kg. The studies have shown that the essential phytochemicals such as Phenolic, Flavonoids and antioxidant capacity and nutritional elements such as Fe and Zn in cereal grains, including rice, are significantly associated with reduced risk of developing diseases (Shen et al. 2009). Also, the highest percentage of diversity (CV %) was observed in traits TAC (41.01%), TCC (72.88%) and Fe (46.55%).

Results of ANOVA for morphological and nutritional quality traits (table is not shown) showed that there was significant difference. Among genotypes for all the studied traits, indicating that there was adequate genetic variation among genotypes. Mean of morphological traits (Table 2) indicates that Onda genotype had the highest (39 cm) and Gharib and Musa-tarom genotypes had the lowest (24 and 24.66 cm, respectively) FLL. The highest FLW had Sepidroud (1.73 cm) and Tarom-danesh (1.53 cm) genotypes. The highest PL was related to Gharib (32.06 cm) and Abjiboji (32.5 cm) genotypes, and the lowest PL was in Onda (25.33 cm) genotype. The smallest grain and the lowest GL to W were for L2

(6.18 mm) and Onda (6.30 mm), and L2 (92.67) and Gharib (2.64), respectively. The highest NFGP and 100GW and the lowest NUGP had L2 (183.83), Onda (3.05) and Abjiboji (4) genotypes, respectively. The ranking of genotypes (Table 2) for morphological traits indicates that the highest rank was Tarom-danesh genotype and the lowest rank were L2 and Fajr genotypes.

Table 1. Statistical properties of traits in rice genotypes

Traits	Mean ± S.D	Min – Max	Number of genotype Min - Max	CV (%)
TAC	45 ± 18.68	19 – 79	Tarom-danesh - L2	41.01
TPC	40.21 ± 5.93	33.82 - 49.29	Abjiboji - Fajr	14.76
TCC	0.87 ± 0.63	0.06 - 2.01	Sepidroud - Amol2	72.88
TSC	72.54 ± 21.43	45.46 - 119.72	Abjiboji - Onda	29.55
TIC	97.74 ± 32.85	45.70 - 146.03	Onda - Abjiboji	33.61
Fe	76.09 ± 35.42	22.07 - 115.90	Amol2 - Sepidroud	46.55
Zn	33.41 ± 9.33	19.66 - 48.42	Sepidroud - Fajr	27.94
FLL	30.50 ± 4.88	24 – 39	Musa-tarom - Onda	16
FLW	1.23 ± 0.22	1.03 - 1.73	Fajr - Tarom-danesh	18.48
PL	29.91 ± 2.53	25.33 - 33.07	Onda - Abjiboji	8.48
GL	9.16 ± 1.95	6.18 - 11.65	L2 - Tarom-danesh	21.38
GW	2.55 ± 0.37	2.09 - 3.29	Onda - Tarom-sadri	14.54
GL to W	3.60 ± 0.74	2.65 - 4.82	Gharib - Musa-tarom	20.66
NFGP	129.85 ± 22.77	106.67 - 183.83	Tarom-danesh - L2	17.54
NUGP	18.06 ± 11.58	4 - 34.17	Abjiboji - Gharib	64.12
100 GW	2.48 ± 0.44	1.61 - 3.13	L2 - Tarom-danesh	17.75

Mean of nutritional quality (Table 2) indicates that the small grain of Fajr and Gharib had the TPC of 49.29 mg GAE/100g and 47.49 mg GAE/100g, respectively. The rice Abjiboji with large grains had the lowest TPC (33.82 mg GAE/100g). The Tarom-danesh genotype had the lowest TAC (19%), and the L2 and Onda had the highest TAC (79% and 77%, respectively). The Fe among these samples varied from 22.07 mg/Kg (ppm) (Amol2 genotype) to 115.90 mg/Kg (ppm) (Sepidroud genotype). The Zn varied from 48.42 mg/Kg (Fajr genotype) to 19.66 mg/Kg (Sepidroud genotype), too. The highest TSC and the lowest TIC was Onda (119.72 mg GLU/100g and 45.70 mg GLU/100g, respectively). The lowest TSC and the highest TIC was Abjiboji (45.46 mg GLU/100g and 146.03 mg GLU/100g, respectively). The ranking of genotypes (Table 2) showed that Onda (45), Gharib and L2 (40) and Fajr (39) had the highest ranks for all nutritional quality. The lowest ranks were for Abjiboji (22), Musa-tarom (28) and Amol2 (29).

Shao et al. (2011) reported the contents of phenolic and flavonoids in different rice genotypes with different grain size. They expressed the phenolic content, flavonoid content and antioxidant capacity in small grains (100.7 mg GAE/100g, 182.6 mg RE/100g and 323.88 µM TEAC/100g, respectively) had higher than the larger grains (42.57 mg GAE/100g, 62.1 mg RE/100g and 230.1 µM TEAC/100g, respectively). The phenolic content and antioxidant capacity of brown rice are higher than the milled rice (Butsat and Siriamornpun, 2010). Shen et al (2009) reported the wider variations of phenolic content, flavonoid content and antioxidant capacity among 423 white rice. To date, rare reports focused on the grain size and its relation to the phytochemicals and antioxidant capacity in Iran.

Correlation analysis

The correlation coefficients among different traits are showed in table 3. In general, the total antioxidant capacity had positive correlation to the phenolic content (r=0.650) and negative correlation to the grain length (r=-0.874) and grain length to width ratio (r=-0.622). The total phenolic content had significant positive correlation to the total soluble carbohydrate (r=0.802) and Zn (r=0.768) and significant negative correlation to insoluble carbohydrate (r=-0.869) and grain length (r=-0.737). The negative correlations between phenolic content and grain length, antioxidant capacity and grain length and also positive correlation between antioxidant capacity and phenolic content reported by Shao et al, (2011), Jin et al, (2009) and Zhang et al, (2010). The total soluble carbohydrate and insoluble carbohydrate had significant negative correlation (r=-0.878), also soluble carbohydrate had negative correlation with grain length (r=-0.685) and the correlation of between insoluble carbohydrate and Zn was negative (r=-0.666). There is no report on the association and correlation between Zn and insoluble carbohydrate, soluble carbohydrate and grain length. The correlations of other traits are shown in Table 3.

In general, the results of correlation showed that with decreasing of grain length and grain length to width ratio can be increased the nutritional quality such as antioxidant capacity, phenolic content, soluble carbohydrate and insoluble carbohydrate reduced as anti-nutritional quality.

Table 2. Mean and ranking of morphological and nutritional quality traits

Traits	Gharib	Onda	L2	Fajr	Sepidroud	Amol 2	Tarom-danesh	Abjiboji	Tarom-sadri	Musa-tarom
FLL	24e	39a	27de	29.66bcde	28.66cde	29.33cde	36ab	34.23abc	32.23bc	24.66e
FLW	1.06b	1.23b	1.16b	1.03b	1.73a	1.23b	1.53a	1.10b	1.03b	1.20b
PL	32.06a	25.33c	28.16abc	30.5abc	31.56ab	26.5bc	30.16abc	32.5a	31.46ab	29.83abc
GL	7.73f	6.30g	6.18g	8.45e	10.44b	9.37d	11.64a	9.63c	10.31b	11.5a
GW	2.92b	2.08e	2.30e	2.14e	2.66c	2.40d	2.57c	2.81b	3.29a	2.38d
GL to W	2.64f	3.02e	2.67f	3.94c	3.92c	3.89c	4.52b	3.42d	3.13e	4.82a
NFGP	124.83d	136bc	183.83a	107.33e	106.83e	140b	133.66bc	106.66e	130.16cd	129.16cd
NUGP	34.16a	30b	32.16ab	5.83ef	14.66d	29.5c	13.33d	4f	6.5e	13.5d
100 GW	2.72b	3.05a	1.60g	2.41de	2.47cd	2.07f	3.13a	2.52c	2.50cd	2.33e
Total ranking	26	26	19	19	28	24.5	37	27	29	27.5
TAC	45b	77a	79a	43b	45b	35c	19d	35c	40bc	37c
TPC	47.49b	45.79c	44.56d	49.29a	37.98e	35.98f	38.01e	33.82i	34.20h	35.01g
TCC	0.57e	1.27c	0.89d	0.20g	0.06h	2.01a	0.79d	0.36f	1.71b	0.85d
TSC	87.41b	119.72a	77.22f	83.17c	68.84f	60.93g	74.17e	45.46j	55.56h	53i
TIC	57.56h	45.70i	96.66f	65.39g	101.97c	135.69b	108.90d	146.03a	118.24c	101.26e
Fe	102.89d	111.23b	65.22f	55.18g	115.90a	22.07j	110.21c	36.76i	43.23h	98.27e
Zn	37.51d	40.92c	43.13b	48.42a	19.66j	21.02i	30.73f	28.36h	34.80e	29.59g
Total ranking	40	45	40	39	32	29	36	22	30.5	28

Table 3. Correlation coefficients among the morphological and nutritional quality traits

Traits	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. TAC	1															
2. TPC	0.650*	1														
3. TCC	0.057	-0.309	1													
4. TSC	0.621	0.802**	-0.025	1												
5. TIC	-0.532	-0.869**	0.236	-0.878**	1											
6. Fe	0.137	0.292	-0.419	0.513	-0.593	1										
7. Zn	0.521	0.768**	-0.132	0.554	-0.666*	0.018	1									
8. FLL	0.027	-0.119	0.188	0.305	0.042	0.011	0.051	1								
9. FLW	-0.187	-0.234	-0.264	0.031	0.119	0.571	-0.598	0.153	1							
10. PL	-0.497	-0.149	-0.585	-0.474	0.175	0.043	-0.100	-0.343	-0.053	1						
11. GL	-0.874**	-0.737*	-0.055	-0.685*	0.567	0.046	-0.630	-0.030	0.396	0.408	1					
12. GW	-0.426	-0.482	0.098	-0.515	0.411	-0.175	-0.316	-0.107	-0.105	0.704*	0.390	1				
13. GL to W	-0.622*	-0.439	-0.123	-0.392	0.305	0.149	-0.433	-0.009	0.436	-0.002	0.803**	-0.231	1			
14. NFGP	0.547	0.146	0.477	0.191	-0.035	-0.066	0.268	-0.118	-0.119	-0.544	-0.462	-0.239	-0.355	1		
15. NUGP	0.521	0.484	0.283	0.587	-0.457	0.280	0.140	-0.237	0.002	-0.474	-0.664*	-0.288	-0.517	0.632*	1	
16. 100 GW	-0.318	0.051	-0.130	0.384	-0.324	0.533	-0.013	0.592	0.238	0.135	0.243	0.129	0.168	-0.507	-0.136	1

*, **: Significant at $p \leq 0.05$ and $p \leq 0.01$ levels, respectively.

Principal component analysis (PCA)

The result of the PCA showed genetic diversity of rice genotypes. The cumulative variance of 89.22% (Table 4) by the first components five with Eigenvalue>1 indicates that traits exhibited great influence. The communalities are a part of variance of a variable that is related to common factors. The high commonalities indicate the more accurate estimation of the variance of the related variable. The first principal component accounted 23.14% of total variance, where by TAC, TPC, TSC and Zn were contributed positive scores and TIC, GL and GL to W were contributed negative scores. The second principal component accounted 20.30% of total variance, in which the TAC, TCC, NFGP and NUGP contributed positively. The third component accounted 14.47% of total variance. The Fe and FLW were variables with contributing positively. Fourth component accounted 11.80% of total variation. The FLL and 100GW contributed positively. The fifth principal component accounted 10.50% of total variance with variables PL and GW. Mahendran et al, (2015) was used principal component to determine relationship among 293 rice germplasm accessions. In this study, the first five components accounted 77.38% of total variance.
A scatter plot was drown between PC1 and PC2 that indicates the suitable grouping of genotypes based on traits, that including Onda, Gharib, Fajr and L2. All the genotypes were widely scattered across quarters (Fig. 1). Guei et al, (2005) suggested that the first three principal component are the most important in variation patterns of genotypes. Finally, on the basis of the three main components, the genotypes of Onda, Fajr, Gharib and L2 were best known.

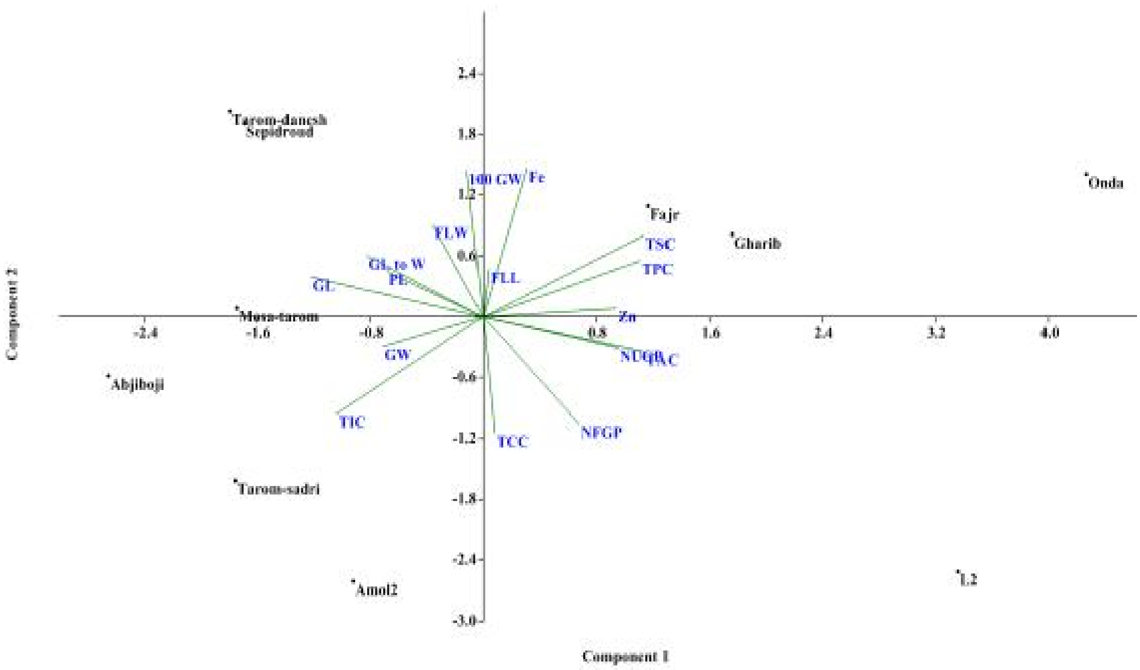

Figure 1. Distribution of traits and genotypes across two first components

Table 4. Eigenvalues, score and contribution of principal components of traits in rice genotypes

Traits	PC1	PC2	PC3	PC4	PC5	Communalities
TAC	0.666	0.568	-0.037	-0.110	-0.083	0.786
TPC	0.945	0.005	0.067	-0.103	-0.118	0.922
TCC	-0.311	0.704	-0.330	0.321	0.009	0.804
TSC	0.813	0.266	0.318	0.356	-0.151	0.982
TIC	-0.895	0.021	-0.301	-0.087	0.075	0.906
Fe	0.317	-0.118	0.886	0.088	-0.009	0.907
Zn	0.841	-0.057	-0.382	0.031	-0.095	0.866
FLL	-0.011	0.046	-0.052	0.916	-0.128	0.860
FLW	-0.348	-0.010	0.826	0.059	-0.188	0.842
PL	-0.109	-0.703	0.021	-0.286	0.629	0.984
GL	-0.792	-0.500	0.199	0.061	-0.026	0.920
GW	-0.392	-0.163	-0.101	0.023	0.881	0.967
GL to W	-0.559	-0.451	0.250	0.025	-0.593	0.931
NFGP	0.127	0.816	-0.093	-0.237	-0.115	0.760
NUGP	0.428	0.750	0.319	-0.187	0.080	0.889
100 GW	0.122	-0.369	0.413	0.774	0.166	0.949
Eigenvalues	5.143	3.248	2.316	1.888	1.681	
Variability (%)	32.141	20.301	14.477	11.802	10.506	
Cumulative (%)	32.141	52.441	66.918	78.720	89.229	

Conclusion

Genotypes of Onda, Gharib, Fajr and L2 had the high total phenol content and Zn and also had the low insoluble carbohydrate and grain length. These genotypes based on the studied traits had the high ranks (Table 2) to other genotypes. The results showed the positive correlation between nutritional quality and negative correlation between morphological traits (grain length and grain length to width ratio) and nutritional quality.

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