J Genet Resour 2024; 10(2): 11-22 *Homepage:* http://sc.journals.umz.ac.ir/

RESEARCH ARTICLE *DOI:* 10.22080/jgr.2024.27293.1394

Investigation of the Morphometric Diversity of Ali Kazemi Rice in Iran

Seyedeh Mahsa Safiedin Ardebili[1], Reza Azizi Nezhad[2], Sara Saadatmand[1], Rahim Ahmadvand[3] and Iraj Mehregan[1*]

[1] Department of Biology, Science and Research Branch, Islamic Azad University, Tehran, Iran
[2] Plant Breeding Department, College of Agriculture and Natural Resources, Islamic Azad University, Science and Research Branch, Tehran, Iran
[3] Department of Vegetables Research, Seed and Plant Improvement Institute, Agricultural Research, Education & Extension Organization, Karaj, Iran

ARTICLE INFO

Article history:
Received 29 March 2024
Accepted 12 May 2024
Available online 25 June 2024

Keywords:
Guilan
North of Iran
Oryza sativa L. (Ali Kazemi rice)

****Corresponding authors:***
✉ I. Mehregan
iraj@daad-alumni.de
imehregan@srbiau.ac.ir

p-ISSN 2423-4257
e-ISSN 2588-2589

ABSTRACT

In this study, the experiment was carried out in a completely randomized design to discover the diversity among 300 Ali Kazemi rice populations from three provinces (ten populations) in the north of Iran using SPSS, Past, Graph Pad, and Excel software. The studies were conducted based on 30 morphological traits. Quantitative traits, like panicle traits, grain length, 100-grain weight, and number of spikelets, demonstrated high variation between populations. Cluster and ordination analyses were performed on morphological characters. The cluster analysis made it possible to divide the Ali Kazemi rice into three sub-clusters of different geographical regions, showing this local variety's adaptability to the environment. Of the three populations, Guilan appeared to be more variable than the Qazvin and Zanjan, as variability was observed among populations for some characters, such as awn length, number of spikelets, blade length, and panicle traits between populations. GLN01 had the highest and shortest average plant height (1185.60 mm). The populations of Guilan also had the longest leaf blade and stem length. The highest value for grain size was also recorded from the Guilan populations. For the ten Ali Kazemi rice populations, the ordinal analysis revealed the traits that cause the greatest variation between populations. Highly significant correlations were found between awn length and traits such as grain length (r = 0.395), panicle length (r = 0.477), panicle weight (r = 0.349), and 100-grain weight (r = 0.440). The highest correlation was between the number of spikelets and some traits, such as plant height, leaf length, culm outer diameter, number of tillers, and panicle traits, indicating that a selection advantage for panicle traits occurs mainly for quantitative traits. Overall, the data collected in the present study could have valuable implications for improving Ali Kazemi rice cultivars in farmers' fields.

Please cite this paper as: Safiedin Ardebili, S. M., Azizi Nezhad, R., Saadatmand, S., Ahmadvand, R., & Mehregan I. (2024). Investigation of the morphometric diversity of Ali Kazemi rice in Iran. *Journal of Genetic Resources*, 10(2), 11-22. doi: 10.22080/jgr.2024.27293.1394.

Introduction

Rice is the second most important cereal after wheat and provides more than two billion people with 60-70% of their daily energy needs, especially in Asia (FAO, 2008). The daily consumption of rice in Asian countries varies between 158 and 178 grams per day (Nogawa and Ishizaki, 1997; Rivai *et al*., 1990). This crop is grown in at least 114 countries and grows up to an altitude of 4,750 meters above sea level (Sharif *et al*., 2013; International Rice Research Institute, 2017). Rice is also the second most consumed food by the Iranian population. In Iran, most rice is grown in the provinces of

Guilan and Mazandaran (northern Iran), which supply 75% of the country's total rice production. The major area of fields under agriculture across different rice varieties belongs to local and aromatic varieties such as Ali Kazemi, which is characterized by the highest values for plant height, panicle length, tillering abilities, 100 g weight, and long awns (Jihad Agriculture Organization of Mazandaran and Guilan, 2018).

Morphological characteristics, especially qualitative ones, are the most important step in plant classification and description (Smith *et al*., 1991). Many studies have been conducted on the relationships and diversity of local rice varieties by way of systematic sampling, using statistical analysis of morphological traits (Oppong-Sekyere *et al*., 2011; Afiukw *et al*., 2016; Sorkheh *et al*., 2016). General phenotypic traits such as plant and blade length, blade width, number of tillers, panicle length, spikelets, grain length, grain width, and 100-grain weight were introduced (Ranawake *et al*., 2013).

Evaluation and characteristics of rice varieties are of great importance due to the growing need for varietal furtherance. The morphological examination of rice genotypes from different geographic regions indicated patterns of character variation, like 100-grain weight and number of spikelets. Besides, it was reported that the size and shape of grain, as well as secondary branching traits, showed the most diversity (Hien *et al*., 2007). The morphological diversity of rice has been analyzed in different studies (Patra & Dhua, 2003).

Pearson's correlation (r) is the most common method that measures the strength and direction of the relationship between morphometric traits. The maximum correlation among the morphometric quantitative traits studied is linked to the length and width of leaf, plant height, panicle length, 100-grain weight, length and width of grain, panicle exertion, panicle secondary branching, the color of awn, grain lemma, and palea color (Sinha and Mishra, 2013). There are strong positive relationships between traits that are useful in improving yield, such as length and weight of panicle, number of grains and productive tillers per plant, and biomass (Tanekar *et al*., 2008).

Since panicle traits are utilized in estimating yield and quality, the association of these characters was quantified, and significant associations, such as the number of spikelets, number of tillers, and panicle length, were demonstrated. In addition, extensive morphological diversity of the panicle traits was illustrated (Wu *et al*., 2016; Yamagishi *et al*., 2003; Sasahara *et al*., 1985; Lei *et al*., 2018).

Local rice is important in agriculture because developments in diversity depend on the prevalence of genes that are likely to be extant only in local varieties. Besides, morphological traits were helpful for the initial assessment of crop development programs and can be used to assess genetic diversity among morphologically recognizable rice populations (Sinha and Mishra, 2013). Therefore, the present study used traits from Ali Kazemi rice samples collected from three provinces in the North of Iran. To find out the diversity among populations of Ali Kazemi rice (*O. sativa*), this research also tried to show the various patterns of traits and samples in different geographical agricultural fields.

Materials and Methods

Field experiments and character evaluation

The plant material for this study comprised 300 Ali Kazemi rice (*Oryza sativa* L.) accessions collected from ten Ali Kazemi cultivation areas (five major farmlands of Guilan: Lakan, Fuman, Sowme' eh Sara, and Lowshan), two areas in Qazvin (Tarom, Sofla), and three productions in Zanjan province (Zanjanrud) in the north of Iran (Table 1 and Fig. 1). All specimen locations were recorded using a handheld Global Positioning System (GPS). In sampling at each place, a distance of 20 meters was evaluated between samples, and three samples were taken. Voucher specimens were deposited in the Herbarium of Islamic Azad University (IAUH) (Table 1).

Morphological traits

Thirty morphological traits (22 quantitative and eight qualitative) were objected to in evaluating ten Ali Kazemi Rice populations. The traits were classified into three categories: whole plant, panicle traits, and grain characters.

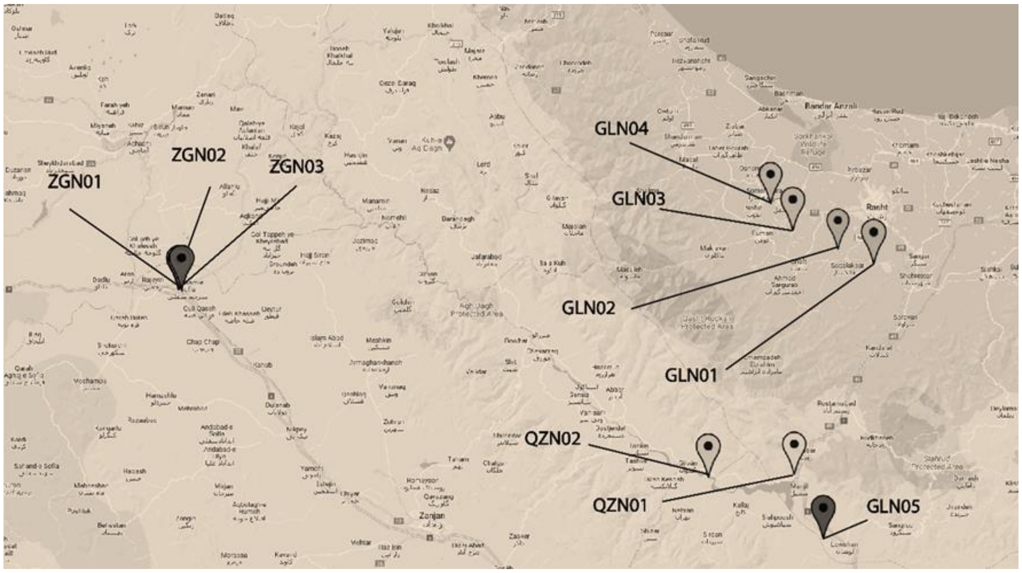

Fig. 1. Collection areas from local Ali Kazemi rice (*Oryza sativa* L.) specimens.

Table 1. Ali Kazemi rice (*Oryza sativa* L.) population list and their localities.

Populations	Code	Locality	Longitude	Latitude	Altitude	Voucher No.
Pop 1	GLN01	Guilan; Lakan, Tekhsem	49°35'4.289"	37°10'13.478"	48	IAUH-1610
Pop 2	GLN02	Guilan; Lakan, Siah Golvandan	49°29'53.383"	37°11'55.728"	18	IAUH-1611
Pop 3	GLN03	Guilan; Fuman, Rud Pish	49°23'14.060"	37°14'2.213"	12	IAUH-1612
Pop 4	GLN04	Guilan; Sowme' eh Sara, Fashkham	49°19'56.770"	37°17'4.866"	3	IAUH-1613
Pop 5	GLN05	Guilan; 90 km from Qazvin to Guilan, Lowshan	49°27'44.687"	36°38'43.946"	310	IAUH-1616
Pop 6	QZN01	Qazvin; 104 km from Qazvin to Guilan	49°23'23.665"	36°46'7.933"	256	IAUH-1614
Pop 7	QZN02	Qazvin; Tarom Sofla, Khandan, Namakin	49°10'56.230"	36°45'45.505"	282	IAUH-1615
Pop 7	ZGN01	Zanjan; 104 km from Zanjan to Tabriza, Zanjanrud, Chorouke Sofla	47°53'32.671"	37°7'15.394"	1151	IAUH-1617
Pop 7	ZGN02	Zanjan; 104 km from Zanjan to Tabriza, Zanjanrud, Chorouke Sofla	47°53'28.771"	37°7'20.361"	1145	IAUH-1618
Pop 7	ZGN03	Zanjan; 104 km from Zanjan to Tabriza, Zanjanrud, Chorouke Sofla	47°53'28.771"	37°7'19.668"	1150	IAUH-1619

Statistical analysis

The statistical analyses for the morphological characteristics were carried out using SPSS 26, Past 4.17, and Excel software programs. The differences were calculated by one-way ANOVA, and cluster analysis was carried out to obtain a dendrogram indicating the morphological association of the Ali Kazemi rice populations. Results are revealed as mean ± standard error observations (mean ± SE). Statistical significance was applied at the 5% level ($p< 0.05$). Cluster analysis was done to yield a dendrogram depicting the morphological relatedness of the Ali Kazemi rice populations. Correlation analyses were constructed using Pearson's correlation coefficient using the Graph Pad Prism version 8.0 (Graph Pad Software Inc., San Diego, CA, USA).

Results

Morphological traits

The quantitative traits varied from one population to another (Table 3). It was found that Guilan populations were observed to have the highest awn length, culm length, plant height, grain length, 100-grain weight, panicle, and panicle weight, while QZN02 was found to have the shortest of them. Among the populations, the highest blade length (504.10 mm) and awn length (50.07 mm) were obtained for the GLN01 population, in addition to the GLN02 and QZN02 populations, which had the maximum and minimum panicle weight (2.41 and 0.79 g, respectively). The GLN01 population showed the highest variation for 100-grain weight, in contrast to the lowest for grain width, which was for the population of ZGN01 (2.54 mm), and illustrated the same template for the length of the glumes. The highest last internode length (431.93 mm) was obtained for the GLN02 population, and the lowest (296.93 and 293.82 mm) belonged to ZGN01 and ZGN02. It was also observed that ZGN02 had the lowest amount of ligule length (10.43 mm); however, there was no compelling difference among the populations of Qazvin in ligule length. There were no significant differences in the number of internodes or primary branch numbers. In this review, Guilan populations have the longest awn, and Zanjan is in the second rank (Table 3). The distribution of panicle traits was also high in Guilan populations. The results revealed a significant variation among the ten groups of Ali Kazemi rice from various regions in the North of Iran (Fig. 2).

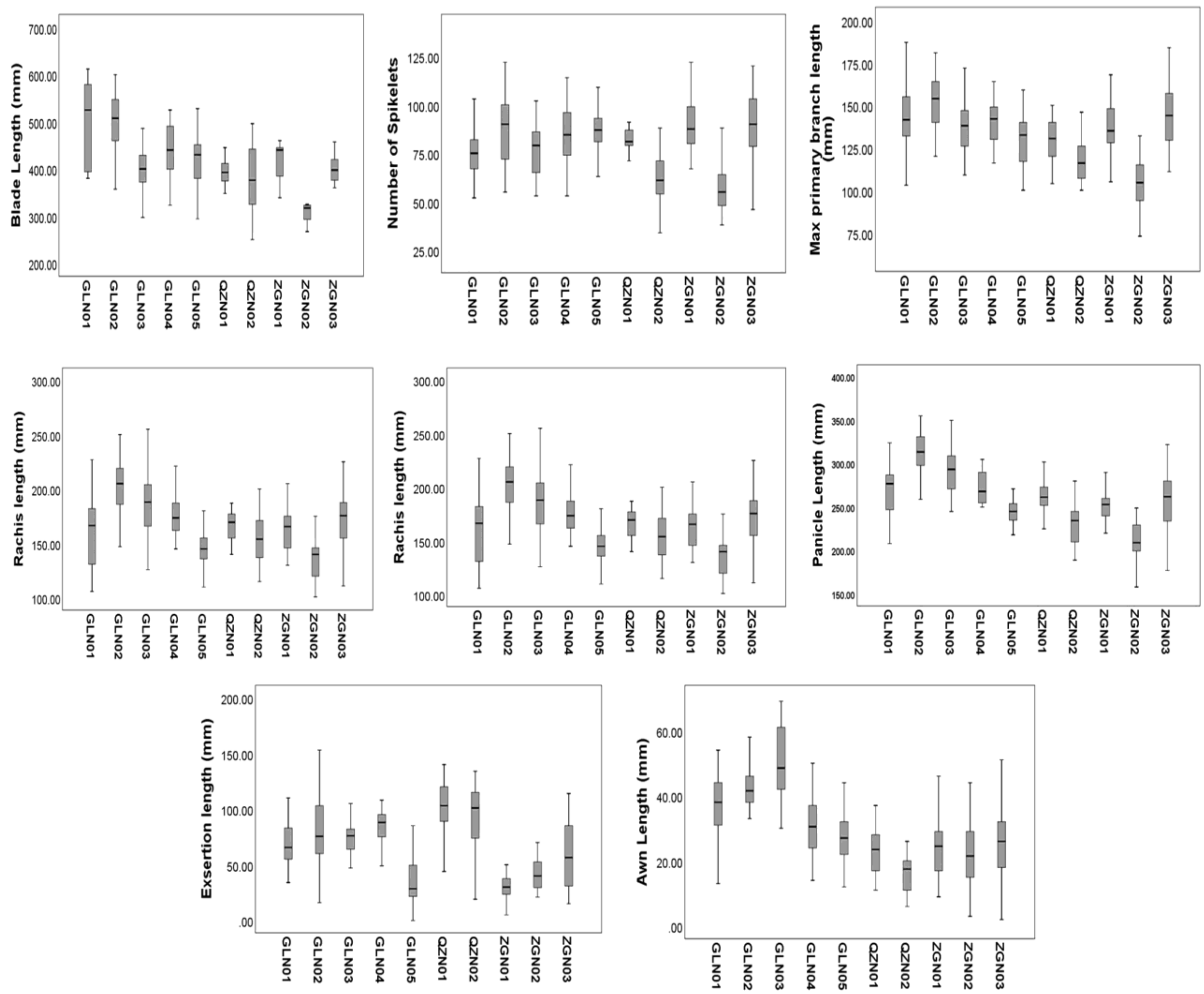

Fig. 2. Distributions of panicle and some morphological traits: Ten populations of Ali Kazemi rice divided by the Guilan (GLN01, GLN02, GLN03, GLN04 and GLN05), Qazvin (QZN01 and QZN02) and Zanjan (ZGN01, ZGN02 and ZGN03).

According to the results, the length and color of the awn conveyed great variability between populations of provinces, so the populations were divided into three groups. In Qazvin, it was ‘‘Straw’’, whereas in Guilan, it was ‘‘Brown", and in Zanjan, it was ‘‘Gold’’. Populations of Guilan (GLN03, GLN02, GLN01, GLN04, and GLN05) presented the higher means, 50.07, 42.38, 37.12, 31.7, and 27.07 mm, respectively, while populations of Qazvin (QZN02 and QZN01) manifested the lower means for this character (16.92 and 24.39 mm, respectively) (Table 3).

Table 3. Descriptive statistics in ten populations of Ali Kazemi rice for quantitative traits.

Pops	**Gl**	**GW**	**WG**	**LG**	**PL**	**PW**	**MI**	**RL**	**MP**	**EL**
GLN01	9.70± 0.47	2.85±0.14	1.35±0.10	2.83±1.08	268.8±31.24	1.82±0.56	43.73±5.87	162.76±35.44	143.63±21.64	68.90±18.67
GLN03	10.07±0.41	2.85±0.17	1.39±0.09	2.42±0.31	291.10±24.75	2.01±0.46	44.13±5.42	185.23±27.21	137.47±15.88	74.62±13.97
GLN04	9.96± 0.40	2.67±0.16	1.32±0.10	2.69±0.43	272.3±17.47	1.96±0.48	42.7± 4.53	174.37±20.31	139.70±11.84	84.65±15.98
GLN05	9.71± 0.39	2.67±0.17	1.19±0.17	2.57±0.71	245.93±13.93	1.85±0.32	36.13±5.28	145.13±16.70	129.90±14.76	33.96±19.95
QZN01	9.53± 0.34	2.61±0.15	1.10±0.06	2.18±0.37	263.4±17.87	1.79±0.23	40.93±5.37	166.57±14.67	130.17±11.93	102±21.78
QZN02	9.36± 0.33	2.44±0.19	0.99±0.06	2.33±0.33	230.67±24.00	0.79±0.30	37.9± 4.07	153.72±21.33	117.57±11.63	92.11±28.09
ZGN01	9.51± 0.32	2.54±0.16	1.14±0.12	2.15±0.35	251.45±18.22	1.71±0.39	39.7± 6.35	162.03±20.48	135.6±15.76	29.89±12.30
ZGN02	9.70± 0.41	2.67±0.18	1.24±0.11	3.71±0.91	213.37±21.04	1.25±0.22	35.65±4.80	137.15±20.64	104.81±15.44	338.09±15.06
ZGN03	9.65± 0.52	2.69±0.15	1.32±0.22	3.91±0.68	256.57±33.74	2.30±0.53	42.74±5.80	170.82±26.27	143.32±19.27	60.08±29.66
Total	9.72± 0.45	2.67±0.20	1.25±0.17	2.73±0.85	261.11±35.26	1.80±0.60	40.69±5.87	166.54±29.38	133.70±20.11	69.22±31.45

Pops	**NS**	**AL**	**LL**	**UL**	**NT**	**BL**	**BW**	**PH**	**NI**	**LI**
GLN01	75± 13.07	37.12±10.24	13.60±2.40	908.70±147.41	17.22±3.10	504.10±85.49	7.78±1.23	1185.60 ±156.98	4± 3.57	389.43 ±41.84
GLN03	77.67±13.96	50.07±11.44	12.90±2.13	1011.23±78.41	12.20±2.40	401.58±44.46	6.97±0.58	1283.47 ±84.02	3.70± 0.47	414.86 ±26.01
GLN04	84.60±15.80	31.70±9.97	14.59±1.73	964.20±65.22	15.30±3.55	437.53±61.78	6.64±0.44	1237.20 ±66.90	3.63± 0.49	422.93 ±28.57
GLN05	87.33±2.10	27.07±8.01	14.32±2.23	836.07±42.19	23.10±5.35	414.89±77.71	8.09±1.02	1091.13 ±46.59	4± 0.00	304 ±21.18
QZN01	81.93±5.52	23.72±7.69	13.98±2.19	941.80±77.49	19.20±6.20	393.58±29.08	7.51±0.82	1211.43 ±77.05	4± 0.00	400.23 ±18.49
QZN02	62.48±0.00	16.91±5.53	13.38±2.05	859.97±87.23	12.31±2.22	380.36±72.67	7.39±0.49	1090.53 ±93.60	4± 0.00	365.33 ±46.12
ZGN01	89.37±15.29	24.56±9.39	15.56±2.47	896.90±76.57	20.80±10.34	414±46.13	7.86±1.29	1160.55 ±88.70	3.83± 0.38	296.93 ±30.17
ZGN02	56.54±11.01	21.93±9.52	10.43±2.60	695.64±77.94	7.20±2.17	305.11±22.21	5.42±0.76	913.37 ±84.49	3.48± 0.51	293.82 ±37.76
ZGN03	89.74±17.29	26.11±10.69	11.92±2.64	832.50±96.70	12.20±5.98	400.50±32.10	8.72±1.37	1094.43 ±132.29	3.7± 0.53	342.57 ±47.08
Total	79.62±17.55	30.16±13.19	13.70±2.53	904.76±133.45	15.50±6.78	419.01±77.72	7.45±1.20	1168.66 ±155.41	3.79± 0.41	366.41 ±61.44

Note: GLN01: Tekhsem; GLN02: Siah Golvandan; GLN03: Fuman; GLN04: Sowme' eh Sara; GLN05: Lowshan; QZN01: Qazvin to Guilan; QZN02: Tarom Sofla; ZGN01: Zanjanrud; ZGN02: Zanjanrud; ZGN03: Zanjanrud. NS: Number of spikelets per panicle; AL: Awn Length; LL: Ligule Length; UL: Culm Length; CD: Culm Outer diameter; NT: Number of tillers; BL: Blade length; BW: Blade width; PH: Plant height; NI: Number of Internodes; LI: Last Internode Length; GL: Grain length; GW: Grain width; WG: 100grain Weight; LG: Length of glumes; PL: Panicle Length; PW: Panicle Weight; PN: Primary branch number; MI: Max internode length; RL: Rachis length; MP: Max primary branch length; EL: Exsertion length.

For the other traits, such as blade width, GLN01 and GLN05 had the highest among the Guilan populations (504.1 and 8.09 mm, respectively). Moreover, the population of GLN05 (Lowshan), which is located between Guilan and Qazvin, showed a middle range of values between populations of Qazvin and Guilan in many traits; for instance, awn length, last internode length, grain length, and width, panicle length and panicle weight, maximum internode length, rachis length, and max primary branch length (Table 3).

Cluster and ordination analyses

Two main groups were formed in the cluster analysis (Ward method phenogram of morphological characters): Group A and B. The subgroups A1 and A2 mainly comprised populations from the Guilan region (GLN02, GLN04, GLN03, GLN01, and GLN05), respectively**.** These populations displayed the longest awn length, long culm length, plant height, longest and widest grain, and longest panicle length (Fig. 3A). Cluster B comprised two populations from Qazvin and Zanjan; they have short awn, short culm, short plant, short panicle, and small grain size. The Qazvin populations (QZN01 and QZN02), placed in subgroup B1, displayed the shortest awn, shortest blade, smallest grain size, and shortest value for 100-grain weight. B2 comprises Zanjan populations (ZGN01, ZGN02, and ZGN03) with the shortest ligule, longest glumes, and shortest last internode. They are separated from the Qazvin group in awn length, blade length, length of glumes, grain size, and 100-grain weight, which is higher in Zanjan populations but not in culm length, culm outer diameter, plant height, and last internode length (Fig. 3A). In ordination analysis, PCA phenogram of morphology characters shows mostly a similar pattern of results with Ward method phenogram and populations of three provinces divided from each other. Separated characters of the populations are the number of spikelets, blade width, plant height, panicle length, length of glumes, grain length, grain width, 100-grain weight, awn length, primary branch number, and panicle weight, which show high diversity in ten populations of Ali Kazemi rice (Fig. 3A). Scree test illustrated the maximum variance of the total amount explained by PCA 1 about 43.41% (Fig. 3B).

Correlation analysis

The phenotypic correlation coefficients among the 30 morphological characters of the Ali Kazemi rice populations are shown in Fig. 4. In the present review, culm length (mm) and panicle length (mm) were positively correlated (r = 0.640). In short, the higher plants always showed longer awn (r = 0.379), number of spikelets (r = 0.317), longer last internode (r = 0.703), thicker culm (r = 0.240), and longer blade (r = 0.370), higher for 100-grain weight (r = 0.177) and panicle weight (r = 0.362), but low for the length of glumes (r = -0.334). The correlation coefficients of the samples were demonstrated along with their grain traits: grain length and grain width (r = 0.176). Characters that show a most remarkable correlation with these two traits were positively correlated with length of grain, awn, and culm (r = 0.208 and 0.395, respectively), and also grain width with awn length (r = 0). .311), awn color (r = 0.429), and hulls color (r = 0.353), respectively. For the relationship between ligule lengths and grain traits, such as awn length (mm), awn color, 100-grain weight, and length of glumes, an appreciably negative association was found; however, this association is significantly positive with the number of spikelets, plant height, and blade length (mm). A strong positive association was found between the length of the glumes and 100-grain weight (r = 0.253). In comparison, a remarkably negative relationship was found between the length of glumes (mm) and a set of data like culm length (r = -0.334), last internode length (r = -0.217), panicle length (r = -0.174), primary branch number (r = -0.248), exsertion length (r = -0.223), and number of tillers (r = -0.252). The correlation analysis revealed positive associations between some traits, independent of the panicle traits, such as panicle length, panicle weight, number of primary branches, maximum internode length, rachis length, maximum primary branch length, and exsertion length (Fig. 4). According to the results of analysis, a significantly positive association between panicle traits and grain traits (grain length and 100-grain weight) was revealed.

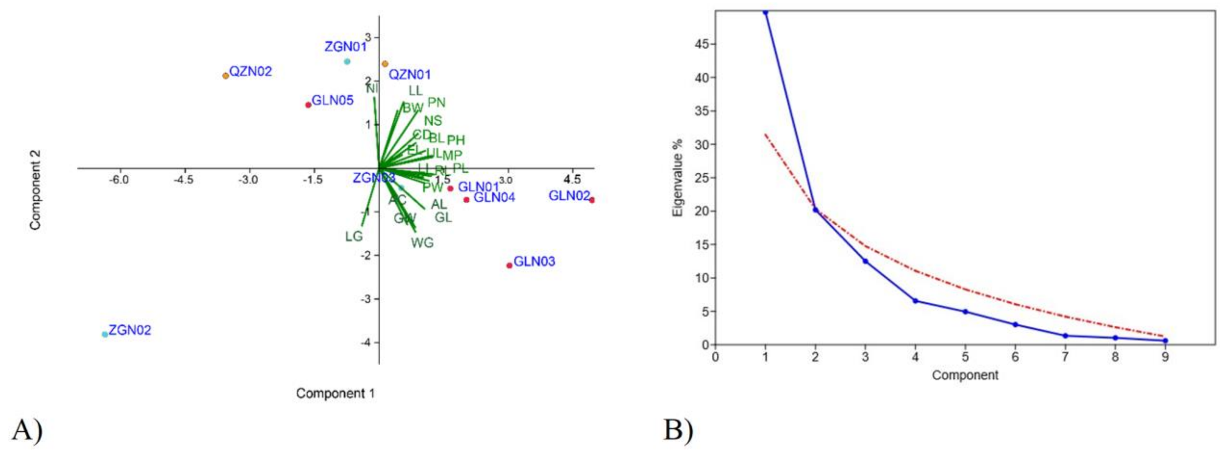

Fig. 3. A) PCA and B) scree plot of morphology characters and separated characters the populations of Ali Kazemi rice: Populations abbreviations: GLN01= Tekhsem, GLN02= Siah Golvandan, GLN03= Fuman, GLN04= Sowme' eh Sara, GLN05= Lowshan, QZN01= Qazvin to Guilan, QZN02= Tarom Sofla, ZGN01= Zanjanrud, ZGN02= Zanjanrud, ZGN03= Zanjanrud, Characters abbreviations: NS= Number of Spikelets, AL= Awn Length, AC= Awn Color, LL= Ligule Length, UL= Culm Length, BL= Blade Length, PH= Plant Height, NI= Number of Internodes, LI= Last Internode Length, GW= Grain width, WG= 100grain Weight, LG= Length of Glumes, PL= Panicle Length, PW= Panicle Weight, HC= Hulls Color, PN= Culm Outer diameter, MI= Max internode length, RL= Rachis length, MP= Max primary branch length.

Discussion

In the present study, the value of the ten Ali Kazemi rice groups from Iran was investigated in terms of phenotypic diversity and the dissection of morphological traits contributing to variability. This seems to be consistent with what was indicated in previous research (Yawen *et al*., 2003; Chakravorty *et al*., 2013; Mangosongo *et al*., 2019). Traits for plant height, tillering ability, and panicle phenotypes such as total grain weight, grain number, and grain size led the most to morphometric diversity and intimated distinct distributions among populations of rice, which is compatible with the earlier results (Sakamoto & Matsuoka, 2008; Ikeda *et al*., 2004; Kobayashi *et al*., 2003; Li *et al*., 2003; Crowell *et al*., 2016). In the current analysis, awn length, grain length, and 100-grain weight had similar patterns (populations of Guilan with the highest values); however, this pattern was not seen regarding the number of spikelets per panicle (populations of Zanjan exposed with the highest values) (Table 3). It appears that an increase in the number of spikelets is affected by increasing leaf area or photosynthesis sources, which are related to blade length and blade width traits. However, ecological and cultural factors influence plant height and the number of grains per panicle. This finding is supported by Saif-Ur-Raisheed et al. (2002) and Ghosh et al. (2004). Cluster analysis successfully classified samples into two main clusters based on morphological characteristics (Fig. 3A). The fact that populations mostly varied in panicle weight, 100-grain weight, number of spikelets, color, and length of awn may indicate the highest variation, and there were effective and grouped genotypes, indicating the reliability of the classification. Related findings were revealed by earlier research studies in rice for various morphological traits (Sarwar *et al*., 2015; Babajanpour *et al*., 2018; Islam *et al*., 2018). It should be noted that grain length and width determine the grain shape, which is a flavor preference characteristic for consumers. It has been shown that there is a positive relationship between traits such as awn length and grain length, number of spikelets with plant height, panicle traits, and length of glumes with grain weight and width, along with other reports (Bessho-Uehara *et al*., 2016; Zhang et al., 2019; Wang *et al*., 2018; Sun *et al*., 2016; Akram *et al*., 1982; Eidi Kohnaki *et al*., 2013; Ranawake *et al*., 2013; Huang *et al*., 2017; Wang *et al*., 2017; Guo *et al*., 2020a). Chen *et al*. (2021) revealed the various biochemical pathways involved in grain weight, leading to expanded glume cells and, finally, increased grain weight.

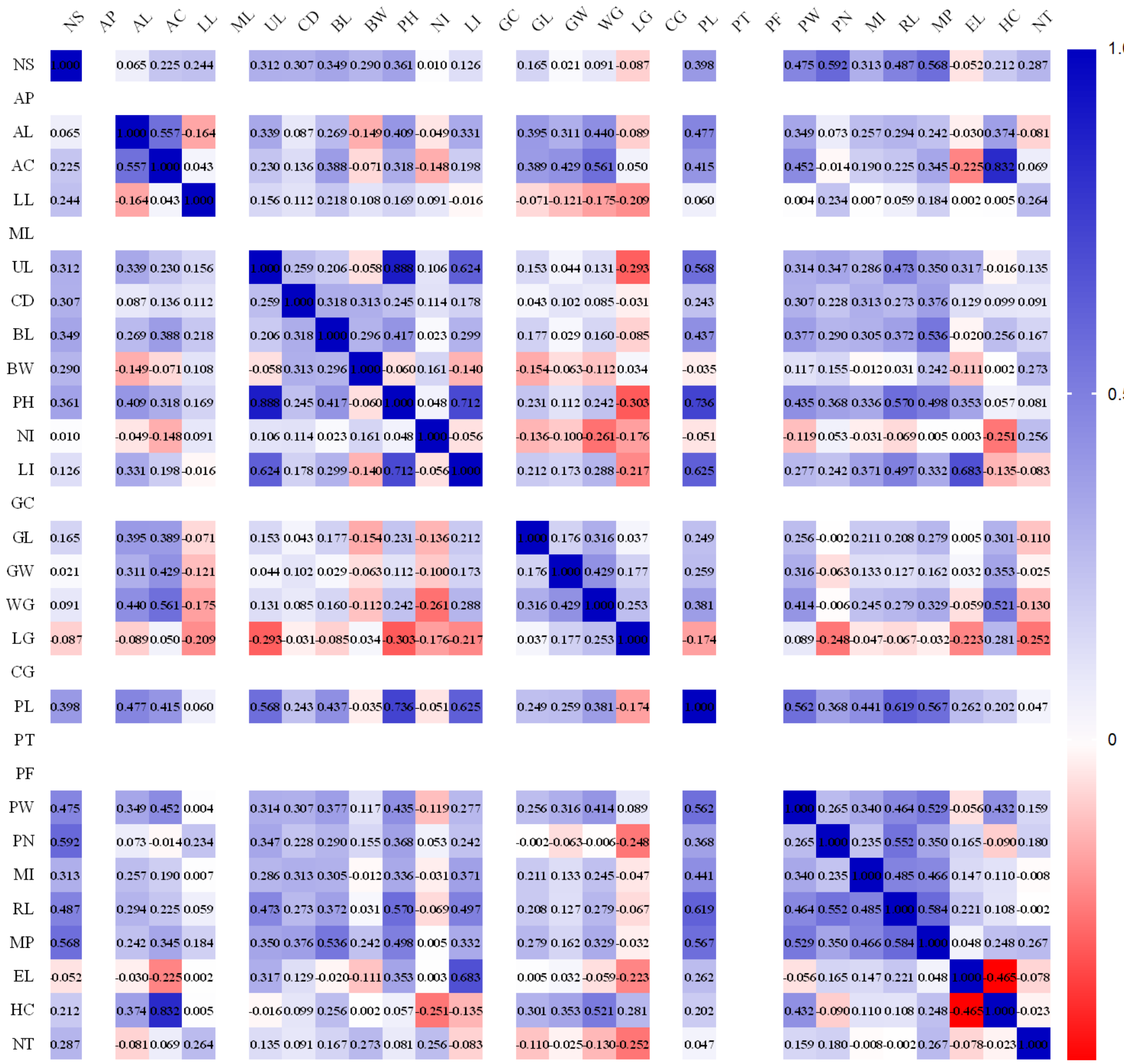

Fig. 4. Heatmap illustrated Pearson's correlation coefficients between ten populations of Ali Kazemi rice: NS= Number of Spikelets, AP= Awn Presence, AL= Awn Length, AC= Awn Color, LL= Ligule Length, ML= Marginal of Ligule, UL= Culm Length, BL= Blade Length, BW= Blade Width, PH= Plant Height, NI= Number of Internodes, LI= Last Internode Length, GC= Grain color, GL= Grain length, GW= Grain width, WG= 100grain Weight, LG= Length of Glumes, CG= Color of Glumes, PL= Panicle Length, PT= Panicle Type, PF= Panicle Form, PW= Panicle Weight, HC= Hulls Color, CD= Culm Outer diameter, PN= Culm Outer diameter, MI= Max internode length, RL= Rachis length, MP= Max primary branch length, EL= Exsertion length, NT= Number of Tillers.

Ordination analysis showed the separated characters of ten Ali Kazemi rice populations—the traits that cause the most variation among populations. Separated characters of the ten populations are the number of spikelets, awn color, length of glumes, grain width, 100-grain weight, awn length, culm outer diameter, number of internodes, and ligule length (Fig. 3A). The results of PCA indicated that traits such as number of spikelets, awn color, length of glumes, grain width, 100-grain weight, awn length, culm outer diameter, number of internodes, and ligule length were the most important discriminating traits (Fig. 3A). Together with other rice diversity studies, PCA would allow the selection of desirable recombinants for different traits (Govintharaj et al., 2018). This clarification of the relative value of the traits could thus be a reliable guide for formulating an effective selection strategy for further rice improvement programs.

Additionally, a positive correlation was obtained between 100-grain weight and panicle length, panicle weight, max internode length, rachis length, and max primary branch length (Fig. 4) (Xu *et al*., 2002; Sakamoto and Matsuoka, 2008). Positive associations were also observed between traits such as culm length, panicle length, and primary branch number (r = 0.240, 0.243, and 0.228, respectively) (Chakravorty *et al*., 2013). Counting them all and the variables of morphological characters between these populations is important to farmers, especially to spread risk during critical unpredictable climate changes such as dehydration and the global warming phenomenon. This clustering pattern will help formulate conventional breeding strategies for crop advancement. Moreover, with the relatively high diversity of Ali Kazemi rice characters in the cultivation areas that are not limited to the north of Iran, such as Qazvin and Zanjan, it is possible to cultivate it in other provinces with similar climatic conditions, and it is better to include this favorable traditional rice in the future research program of this favorable traditional rice.

Conclusion

The clearest finding obtained from this study is significant statistical differences between all ten examined populations of Ali Kazemi rice in terms of morphological characteristics. Most of them were related to each other. Cluster analysis of the traits placed all ten populations into three groups (Fig. 3A). Notable differences were observed in all 30 morphological characters, confirming the existence of diversity among 300 Ali Kazemi rice accession samples. The characters showed variabilities, such as plant height, culm length, blade length, awn color, awn length, and panicle length. Of course, separated characteristics of ten Ali Kazemi rice populations, such as length of glumes, grain width, 100grain weight, awn length, culm outer diameter, number of internodes, and ligule length, showed variability among ten populations, which separated them from each other.

Correlations among all morphological traits were significant, especially among panicle traits, encouraging rapid improvement in yield. As the results showed, the superiority of selection would be suggested for quantitative and panicle traits in our collection. These primitive data can be used for future breeding enhancement programs in traditional rice cultivars.

The diversity of Ali Kazemi rice traits denoted a relatively high level of variation among the 30 traits studied. It can be concluded that Ali Kazemi has become a very diverse traditional variety in different growing areas due to the use of self-seeding and possibly physical mixing of seeds of different varieties and, thus, recombination between them. Consequently, it is recommended that these accessions be preserved in the Iranian rice gene bank and use their advantageous characteristics in breeding programs. This variety is also recommended to be purified to provide farmers with pure seeds of the best accessions.

Acknowledgments

The authors would like to thank the Agriculture-Jihad Organization in the Guilan, Qazvin, and Zanjan provinces of Iran.

Conflict of Interests

The authors declare no conflict of interest.

References

Afiukw, C. A., Faluyi, J. O., Atkinson, C. J., Ubi, B. E., Igwe, D. O., & Akinwale, R. O. (2016). Screening of some rice varieties and landraces cultivated in Nigeria for drought tolerance based on phenotypic traits and their association with SSR polymorphism. *African Journal of.Agricultural Research*, 11(29), 2599-2615. https://doi.org/10.5897/ajar2016.11239

Babajanpour, A., Hashemi-Petroudi, S. H., & Haghpanah, M. (2018). Study of genetic variation of some Iranian rice (*Oryza sativa*) genotypes based on morphological traits physicochemical properties and molecular markers. *Journal of Plant Molecular Breeding*, 6(2), 1-9. https://doi.org/10.22058/jpmb.2018.86951.1159

Bessho-Uehara, K., Wang, D. R., Furuta, T., Minami, A., Nagai, K., Gamuyao, R., … & Asano, K. (2016). Loss of function at RAE2 a previously unidentified EPFL is required for awnlessness in cultivated Asian rice. *Proceedings of the National Academy of Sciences* 113, 8969-8974. https://doi.org/10.1073/pnas.1604849113

Chakravorty, A., Ghosh, P. D., & Sahu, P. K. (2013). Multivariate analysis of phenotypic diversity of landraces of rice of West Bengal. *American Journal of Experimental Agriculture* 3(1), 110- 123. https://doi.org/10.9734/AJEA/2013/2303

Chen, K., Eskowski, A., Jaremko, E., & Jaremko, M. (2021). Genetic and molecular factors determining grain weight in rice. *Frontiers in Plant Science* 12, 605799. https://doi.org/10.3389/fpls.2021.605799

Crowell, S., Korniliev, P., Falcão, A., Ismail, A., Gregorio, G., Mezey, J., & McCouch, S. (2016). Genome-wide association and high-resolution phenotyping link *Oryza sativa* panicle traits to numerous trait-specific QTL clusters. *Nature Communications* 7: 10527. https://doi.org/10.1038/ncomms10527

Eidi kohnaki, M., Kiani, G. H., & Nematzadeh, G. H. (2013). Relationship between morphological traits in rice restorer lines at F3 generation using multivariate analysis. *International Journal of Advanced Biological and Biomedical Research* 1(6), 572-577. https://doi.org/10.26655/ijabbr.2017.9.1

FAO. (2008). Food consumption: pattern of main food items share in total dietary energy consumption. FAO statistic division bulletin. Available at: http://www.fao.org/faostat

Ghosh, M., Mandal, B. K., Mandal, B. B, Lodh, S. B., & Dash, A. K. (2004). The effect of planting date and nitrogen management on yield and quality of aromatic rice (*Oryza sativa*). *Journal of Agricultural Science* 142, 183-191. https://doi.org/10.1017/S002185960400423X

Govintharaj, P., Manonmani, S., & Robin, S. (2018). Variability and genetic diversity study in an advanced segregating population of rice with bacterial blight resistance genes introgressed. *Ciência e Agrotecnologia* 42(3), 291-296. http://doi.org/10.1590/1413-70542018423022317

Guo, L., Chen, W., Tao, L., Hu, B., Qu, G., … & Tu, B. (2020a). *GWC1* is essential for high grain quality in rice. *Plant Science* 296, 110497. https://doi.org/10.1016/j.plantsci.2020.110497

Hien, N. L., Sarhadi, W. A., Oikawa, Y., & Hirata, Y. (2007). Genetic diversity of morphological responses and the relationships among Asia aromatic rice (*Oryza sativa* L.) cultivars. *Tropics* 16(4). https://doi.org/10.3759/tropics.16.343

Huang, K., Wang, D., Duan, P., Zhang, B., Xu, R., … & Li, N. (2017). Wide and thick grain 1 which encodes an otubain-like protease with deubiquitination activity influences grain size and shape in rice. *The Plant Journal* 91, 849-860. https://doi.org/10.1111/tpj.13613

Ikeda, K., Sunohara, H., & Nagato, Y. (2004). Developmental course of inflorescence and spikelet in rice. *Breeding Science* 54, 147-156. https://doi.org/10.1270/JSBBS.54.147

International Rice Research Institute (IRRI). (2017). Available at: https://www.irri.org/

Jihad Agriculture Organization of Mazandaran and Guilan. (2018). Report on Estimation of Level Production and Yield per Crop.

Kobayashi, S., Fukuta, Y., Sato, T., Osaki, M., & Khush, G. S. (2003). Molecular marker dissection of rice (*Oryza sativa* L.) plant architecture under temperate and tropical climates. *Theoretical and Applied Genetics* 107: 1350-1356. https://doi.org/10.1007/s00122-003-1388-8

Lei, Q., Zhou, J., Zhang, W., Luo, J., Wu, K., & Long, C. H. (2018). Morphological diversity of panicle traits in Kam fragrant glutinous rice (*Oryza sativa*). *Genetic Resources and Crop Evolution* 65, 775-786. https://doi.org/10.1007/s10722-017-0570-9

Li, Z. K., Yu, S. B., Lafitte, H. R., Huang, N., Courtois, B., … & Hittalmani, S. (2003). QTL x environment interactions in rice. I. heading date and plant height. *Theoretical and Applied Genetics* 108, 141-153. https://doi.org/10.1007/s00122-003-1401-2

Mangosongo, H., Lyaruu, H., & Mneney, E. (2019). Agro-morphological characterization of the wild rice (*Oryza longistaminata*) populations from selected areas of Tanzania. *Tanzania Journal of Science* 45(1), 9-17. https://doi.org/10.4314/tjs.v45i1

McCouch, S., Wright, M., Tung, C. W., Maron, L., McNally, K., … & Fitzgerald, M. (2016). Open access resources for genome wide association mapping in rice. *Nature Communications* 7, 10532. https://doi.org/10.1038/ncomms10532

Nogawa, K., & Ishizaki, A. (1979). A comparison between cadmium in rice and renal effects among inhabitants of Jinzu river Basin. *Environmental Research* 18, 410-420. https://doi.org/10.1016/0013-9351(79)90117-8

Oppong-Sekyere, D., Akromah, R., Nyamah, E. Y., Brenya, E., & Yeboah, S. (2011). Characterization of okra (*Abelmoschus* spp.) germplasm based on morphological characters in Ghana. *Plant Breeding and Crop Science* 3(13), 368-379. https://doi.org/10.5897/jpbcs.9000022

Patra, B. C., & Dhua, S. R. (2003). Agro-morphological diversity scenario in upland rice germplasm of Jeypore tract. *Genetic Resources and Crop Evolution* 50, 825-828. https://doi.org/10.1023/a:1025963411919

Ranawake, A. L., Amarasingha, U. G. S., & Dahanayake, N. (2013). Agronomic characters of some traditional rice (*Oryza sativa* L.) cultivars in Sri Lanka. *Journal of the University of Ruhuna* 1(1), 3-9. https://doi.org/10.4038/jur.v1i1.6150

Rivai, I. F., Koyama, H., & Suzuk, S. (1990). Cadmium content in rice and its intake in various countries. *Bulletin of Environmental Contamination and Toxicology* 44, 910-916. https://doi.org/10.1007/BF01702183

Saif-ur-Raisheed, M., Ahmad Sadaqat, H., & Babar, M. (2002). Cause and effect relations of panicle traits in rice (*Oryza sativa* L.). *Asian Journal of Plant Sciences* 1(2), 23-125. https://doi.org/10.3923/ajps.2002.123.125

Sakamoto, T., & Matsuoka, M. (2008). Identifying and exploiting grain yield genes in rice. *Current Opinion in Plant Biology* 11(2), 209-214. https://doi.org/10.1016/j.pbi.2008.01.009

Sarwar, G., Hossain, M. S, Harun-Ur-Rashid, M., & Parveen, S. (2015). Assessment of genetic variability for agro-morphological important traits in Aman rice (*Oryza Sativa* L.). *International Journal of Applied Sciences and Biotechnology* 3(1), 73- 79. https://doi.org/10.3126/ijasbt.v3i1.11896

Sasahara, T., Abe, N., & Kambayashi, M. (1985). Inheritance of panicle types classified by the nodal distribution pattern of secondary spikelets in rice (*Oryza sativa* L.). *Japanese Journal of Breeding* 35, 32-40. https://doi.org/10.1270/jsbbs1951.35.32

Sharif, M. K., Butt, M. S., Anjum, F. M., & Khan, S. H. (2014). Rice bran: A novel functional ingredient. *Critical Reviews in Food Science and Nutrition* 54(6), 807-16. https://doi.org/10.1080/10408398.2011.608586

Sinha, A. K., & Mishra, P. K. (2013). Agro-morphological characterization and morphology based genetic diversity analysis of landraces of rice variety (*Oryza sativa* l.) of bankura district of West Bengal. *International Journal of Current Research* 5(10), 2764-2769. https://journalcra.com/article

Smith, S. E., Al-Doss, A., & Warburton, M. (1991). Morphological and agronomic variation in North African and Arbian alfalfas. *Crop Science* 31, 1159-1163. https://doi.org/10.2135/cropsci1991.0011183X003100050016x

Sorkheh, K., Masaeli, M., Chaleshtori, M. H., Adugna, A., & Ercisli, S. (2016). AFLP-based analysis of genetic diversity, population structure, and relationships with agronomic traits in rice germplasm from North region of Iran and world core germplasm set. *Biochemical Genetics* 54(2), 177-93. https://doi.org/10.1007/s10528-016-9711-7

Sun, P., Zhang, W., Wang, Y., He, Q., Shu, F., … & Liu, H. (2016). OsGRF4 controls grain shape panicle length and seed shattering in rice. *Journal of Integrative Plant Biology* 58(1), 836-847. https://doi.org/10.1111/jipb.12473

Tanekar, K., Rastogi, N. K., Tirkey, P., & Sahu, L. (2008). Correlation and path analysis of yeild and its components in rice germplasm accession. *Plant Archives* 8(2), 887-889. https://doi.org/10.9787/pbb.2023.11.2.117

Wang, S., Wu, K., Qian, Q., Liu, Q., Li, Q., … & Pan, Y. (2017). Non-canonical regulation of SPL transcription factors by a human OTUB1-like deubiquitinase defines a new plant type rice associated with higher grain yield. *Cell Research* 27, 1142-1156. https://doi.org/10.1038/cr.2017.98

Wang, T., Zou T, He Z., Yuan, G., Luo, T., … & Zhu, J. (2018). Grain length and awn 1 negatively regulates grain size in rice. *Journal of Integrative Plant Biology* 61(10), 1036-1042. https://doi.org/10.1111/jipb.12736

Wu, Y., Huang, M., Tao, X., Guo, T., Chen, Z., & Xiao, W. (2016). Quantitative trait loci identification and meta-analysis for rice panicle-related traits. *Molecular Genetics and Genomics* 291(5), 1-14. https://doi.org/10.5555/20163309199

Xu, J. Y., Xue, Q. Z., Luo, L. J., & Li, Z. K. (2002). Genetic dissection of grain weight and its related traits in rice (*Oryza sativa* L.). *Chinese Journal of Rice Science*. 16, 6-10 (in Chinese with an English abstract). https://doi.org/10.5555/20023025934

Yamagishi, J., Nemoto, K., & Mu, C. (2003). Diversity of the rachis-branching system in a panicle in *Japonica* rice. *Plant Production Science* 6, 59-64. https://doi.org/10.1626/pps.6.59

Yawen, Z., Shiquani, S., Zicho, L., Zhongyi, Y., Xiangkun, W., Hongliang, Z., & Guosong, W. (2003). Ecogeographic and genetic diversity based on morphological characters of indigenous rice (*Oryza sativa* L.) in Yunnan, china. *Genetic Resources and Crop Evolution*. 50, 567-577. https://doi.org/10.1023/a:1024436501289

Zhang, Y., Zhang, Z., Sun, X., Zhu, X., Li, B., … & Li, J. (2019). Natural alleles of *GLA* for grain length and awn development were differently domesticated in rice subspecies japonica and indica. *Plant Biotechnology Journal* 17(8), 1547-1559. https://doi.org/10.1111/pbi.13080