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Analysis and evaluation of rice grain quality in *Indica* rice (*Oryza sativa* L.)

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Summary

Rice quality is a comprehensive quantitative trait greatly influenced by heredity and environment. Here, 11 rice quality traits and Rapid Visco-Analyser (RVA) profiles of 30 *indica* rice germplasms were detected and analyzed. In addition, we used grain size genes and starch synthesis gene *Wx* to detect the rice quality genotypes of rice. The results showed different degrees of correlation among rice quality traits. In addition, principal component analysis (PCA) divided rice quality traits into four principal components, and the cumulative contribution rate reached 82.478%. Cluster analysis divided 30 rice varieties into five categories. The first four types had better rice quality. Identification of rice quality genes indicated that most of the genotypes were *GS3*, *GS9*, *GW5*, *GW8* and Wx^b, and a few were *GW7* and Wx^a. Identifying rice quality characteristics and genotypes of rice varieties may lay a theoretical foundation for promoting the cultivation of new rice varieties, enabling breeders and researchers to develop better rice varieties.

Keywords: Rice quality; RVA profile; Amylose Content; Cluster analysis

Introduction

Rice grain quality is a comprehensive quantitative trait which has gradually been valued by breeders and researchers in recent years (MENG et al., 2019). At present, the evaluation index of rice grain quality is mainly divided into four classes: processing quality, appearance quality, cooking and eating quality, and nutritional quality (BIRLA et al., 2017, BUTARDO et al., 2019; WANG et al., 2022; ZHANG et al., 2016). The cooking and eating quality of rice is a very complex trait, attributed to numerous factors.

Amylose content (AC), grain size and chalkiness are important for rice appearance quality. *Wx* encodes GBSSI (granule-bound starch synthase I) that controls AC in the endosperm, and natural allelic variation within the locus causes extensive diversity in AC and cooking and food quality in modern rice (ZHANG et al., 2019). There are at least nine types of *Wx* gene allelic variations, including Wx^{lv}, Wx^{a}, Wx^{in}, Wx^{b}, Wx^{mq}, Wx^{mp}, $Wx^{op/hp}$, Wx^{la} and *wx*, have been reported (SANO, 1984; MIKAMI et al., 2008; MIKAMI et al., 1999; LIU et al., 2009; SATO et al., 2002; YANG et al., 2013; ZHANG et al., 2019; ZHOU et al., 2021). *GW7*/*GL7* is a major quantitative trait locus (QTL) for grain length and its expression is directly regulated by *OSSPL16*/*GW8* (WANG et al., 2012; WANG et al., 2015). *GS3*, a major QTL for controlling grain size, plays a negative regulator role in regulating grain and organ size (SUN et al., 2018; MAO et al., 2010). *GS9* is negatively regulated by granule type by altering cell division (LI et al., 2018; ZHAO et al., 2018).

The viscosity of starch, which can be measured with a Rapid Visco-Analyser (RVA) by Australia's Newport Scientific Instruments, is also one of the important traits of cooking and eating quality of rice. (DEFFENBAUGH et al., 1989; REDDY et al., 1994). Starch RVA spectrum characteristics refer to the curve formed by using a certain amount of water and milled rice flour to simulate the cooking process of rice, and using a rapid visco-analyser to measure the viscosity changes of starch paste during the heating, and cooling process of milled rice flour (XUAN et al., 2020), which has the advantages of being speed, simple, accurate and good repeatability by RVA. The profile reveals the peak viscosity (PV), hot paste viscosity (HPV), cool paste viscosity (CPV), peak time (PeT), paste temperature (PaT), breakdown viscosity (BDV), consistency viscosity (CSV), and setback viscosity (SBV) (NAKAMURA et al., 2016; TONG et al., 2014), and they can better reflect cooking and eating quality, especially BDV, SBV and CSV (FAHAD et al., 2016; PANG et al., 2016). RVA spectrum has been widely used in rice grain quality evaluation index, and can reflect the differences in starch quality among different rice varieties (SHI et al., 2022; ALI et al., 2022).

For the past few years, the breeding goal of rice in China has gradually shifted from high-yielding to high-quality, but there are huge challenges for high-quality breeding and variety improvement. Quality-related traits often require the measurement of many indicators, which is difficult for breeders to balance these indicators because of the complex correlation between them (CUSTODIO et al., 2019). Therefore, the objectives of this study were to evaluate the 30 *indica* rice varieties from different main rice producing areas in China, which are participated in the First National High-quality Rice Varieties Field Appraisal Meeting in 2018. To further reveal its quality characteristics, we analyzed their appearance quality, cooking and eating quality and RVA profile, identified the genotypes controlling rice quality traits, by which comprehensively evaluated the grain quality of these rice varieties. These results will provide a theoretical basis for the breeding of new rice varieties with high quality and variety improvement.

Plant materials and method

Plant materials

The 30 high-quality *indica* rice varieties collected from different main rice-producing areas were selected as experimental materials (Tab. S1). All experimental materials were cultivated at the Baiyun experimental station of the Rice Research Institute of Guangdong Academy of Agricultural Sciences in 2019, which were sown on July 21th and transplanted to the experimental field on August 5th. The experiment used a randomized blocks design and set three repetitions. Row spacing was 15cm, and plant spacing was 15 cm. Fertilizer and water management was carried out according to local practices.

Rice grain quality determination

100 g of air-dried rice without damage, disease and pests was taken and stored in a ventilated and drying environment for three months. It was used for the determination of rice quality when the physical and chemical properties of seeds were stable and ripe. Before analysis, samples were put in a dry and ventilated place for about seven days to keep the moisture content of the samples below 14%.

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Appearance quality: Scanning with SC-E Rice Appearance Quality Detector to measure the Length width ratio (L/W) of brown rice and chalky grain rate (CGR), chalkiness degree (CD) and transparency (Tr) of head milled rice.

Cooking and eating quality: After head milled rice was ground, it was passed through 100-mesh screen. Amylose content (AC) and gel consistency (GC) were determined according to the method of "High Quality Paddy" (GB/T17891-2017). Gelatinization temperature of rice was measured by the method of Alkali value (AV), which was determined according to the standard method for "Determination of Rice Quality"(NY/83-2017) Standards of Ministry of agriculture of the people's Republic of China. The taste value (TV) of rice was determined by a rice taster analyzer (SATAKE, Japan). Water was added to 30 g rice sample according to the ratio of 1:1.4 (rice: water), cooked 30 min in the steamer, and braised 5 min. After cooling cooked rice to room temperature 7 ± 1 g was pressed into the pressure ring (kept 10 s). The formed rice pressure ring into the rice taste meter drive test program, the determination of rice taste value.

RVA spectrum characteristic: The paste viscosity of rice starch was measured using a Rapid Visco Analyzer (RVA) by RVA-TecMaster (Perten, Sweden). Briefly, 3 g of rice flour was mixed with 25 mL of water in the RVA sample can. An RVA-Super 3 Viscometer instrument operated using Thermocline Windows control and analysis software version 1.2 was used (Newport Scientific, Australia). Four main traits can be directly obtained from RVA spectrum, which are peak viscosity (PV), hot paste viscosity (HPV), cool paste viscosity (CPV) and Peak time (PeT). At the same time, four derived traits can be calculated: breakdown viscosity (BDV=PV-HPV), setback viscosity (SBV=CPV-PV), Consistence viscosity (CSV=CPV-HPV) and Pasting temp (PaT).

PCR-based genotyping

Plant genomic DNA was extracted from the fresh leaves of heading-stage plants using a previously described CTAB protocol. The molecular markers for genotyping *Wx*, *GS3*, *GS9*, *GW5*, *GW7* and *GW8* were listed in Tab. 1. PCR amplification was performed on a Bio-Rad C1000 Touch Thermal Cycler (USA), and the protocol for PCR amplification with the appropriate parameters was performed as described previously (Liu et al., 2022). The PCR products were detected by a 3.0% agarose gel electrophoresis in 1× TBE buffer.

Data analysis

Statistical analysis was performed with independent samples using the Student's *t-test* to test the significance of differences, and all data are represented as means ± standard deviations (means ± SD). Correlation analysis, principal component analysis (PCA) and cluster analysis were performed by Origin 2022 and SPSS 22.0 software.

Results

Rice quality characters of quality *indica* rice

According to the analysis of rice grain quality of different high quality *indica* rice varieties (Tab. S1). At the 11 rice quality traits, the smaller coefficient of variation (CV) of TV, AV, L/W showed little difference among different varieties. In contrast, the larger CV of GC, Tr, AC, CGA, CD indicated significant difference among them. According to the national standard of GB/T17891-2017 "High Quality Paddy", 83.33% of the rice varieties reached the national processing quality and appearance quality standards, and 96.67% came the national standard in cooking and eating quality.

The primary data of PV, HPV and CPV can reflect the basic characteristics of RVA spectrum (Tab. S1). The CV of PV was the most negligible (3.39%), but the larger CV of HPV and CPV were 19.41 and 20.57, respectively. For the secondary data of RVA spectrum characteristic values, SBV > CSV > BDV, showed significant differences among varieties (Tab. S1).

Rice quality characters analysis of quality *indica* rice

Based on the rice quality traits and RVA spectrum, by using the correlation analysis, the research discussed the correlation among each rice quality traits (Tab. 2). In the appearance quality, the chalkiness of rice significantly affected the transparency. On cooking and eating quality, there is a highly significant negative correlation between AV and GC (-0.513), while there is a highly significant positive correlation with AC (0.603). AC significantly negatively correlated with TV (-0.612) (Tab. 2). These results indicate high gelatinization temperature and poor taste caused by the varieties with low GC and high AC.

On RVA spectrum, PV, HPV, BDV, CPV, SBV, PeT and CSV were significantly correlation, but no significant correlation with PaT (Tab. 2). Toward the secondary data were obtained by RVA spectrum, BDV was extremely significantly negatively correlated with SBV and CSV (-0.974 and -0.832, respectively), as well as SBV was extremely significantly positive correlation with CSV (0.936). In order to explore the correlation between rice grain quality and RVA spectrum characteristic values. Correlation analysis (Tab. 2) showed that the correlation between processing quality, appearance quality and RVA spectrum characteristic values was insignificant, but the CGA was positively correlated with PaT. AC, AV and TV in cooking and eating quality were significantly correlation with many of RVA spectrum, while GC was only extremely significantly negatively correlated with PaT (-0.617) (Tab. 2). These results showed that the RVA spectrum characteristic values could indirectly reflect the cooking and eating quality of rice.

Principal component analysis (PCA) of rice grain quality

PCA can describe the hidden variables that cannot be directly measured from a set of measured variables. Because of BDV, SBV and CSV can better reflect the cooking and eating quality of rice

Tab. 1: Primers used in this work

Gene name	Primer name	Foreard	Reverse	Fragment size	Tm (bp)	References (°C)
Wx	RA19	TACAAATAGCCACCCACACC	TTGCAGATGTTCTTCCTGATG	157bp	56 °C	Li et al., 2009
GS3	Chr301	TATTTATTGGCTTGATTTCCTGTG	GCTGGTTTTTTACTTTCATTTGCC	511bp	56 °C	Zhang, 2018
GS9	In0919	CGTTTAGGCTGGCTGC	CAGTTGGTGGTTTCGTAGAG	192bp	56 °C	Zhang, 2018
GW7/GL7	CHR701	AGGGCTGGGACTGAACTTTGT	ATGGACCCAGGCAAACACC	138bp	56 °C	Zhang, 2018
GW5/qSW5	CHR525	AAGAAAGCCCAAAACAACACA	CTTCCACCCTCAGTGTCGC	206bp	56 °C	Zhang, 2018
GW8/OsSPL16	GW8	AAAGAGACAGCCACGGAATC	ATCTTGAGATCCCACTCCAT	191/181	55 °C	Liu et al., 2018

Tab. 2: Relationships between rice quality

Traits	GL	GW	L/W	Tr	CGA	CD	GC	AC	AV	TV	PV	HPV	BDV	CPV	SBV	PeT	CSV	PaT
GL	1																	
GW	0.416*	1																
L/W	0.480**	-0.557**	1															
Tr	-0.033	0.081	-0.096	1														
CGA	0.132	0.064	0.015	0.564**	1													
CD	-0.041	-0.170	0.057	0.313	0.819**	1												
GC	0.612**	0.173	0.349	0.139	-0.047	-0.128	1											
AC	-0.461*	0.052	-0.467*	-0.127	-0.211	-0.054	-0.226	1										
AV	-0.425*	-0.078	-0.279	-0.342	-0.365*	-0.209	-0.513**	0.603**	1									
TV	0.329	-0.014	0.349	0.015	-0.191	-0.279	0.26	-0.612**	-0.359	1								
PV	0.260	-0.206	0.441*	0.103	0.163	0.191	0.207	-0.619**	-0.535**	0.382*	1							
HPV	-0.169	0.182	-0.380	0.009	0.212	0.301	-0.253	0.562**	0.354	-0.855**	-0.423*	1						
BDV	0.224	-0.216	0.455*	0.027	-0.118	-0.182	0.274	-0.662**	-0.466**	0.822**	0.675*	-0.954**	1					
CPV	-0.298	0.137	-0.438*	-0.014	0.133	0.22	-0.313	0.644**	0.445*	-0.886**	-0.493**	0.962**	-0.946**	1				
SBV	-0.316	0.163	-0.478**	-0.034	0.083	0.153	-0.319	0.696**	0.504**	-0.860**	-0.644**	0.935**	-0.974**	0.983**	1			
PeT	-0.398*	0.148	-0.502**	0.074	0.329	0.296	-0.617**	0.379*	0.358	-0.566**	-0.470**	0.718**	-0.714**	0.742**	0.751**	1		
CSV	-0.427*	0.065	-0.464**	-0.040	0.020	0.093	-0.354	0.677**	0.511**	-0.828**	-0.528**	0.807**	-0.832**	0.938**	0.936**	0.689**	1	
PaT	0.382*	0.369*	-0.047	0.255	0.437*	0.178	0.026	-0.506**	-0.440*	0.206	0.437*	-0.023	0.164	-0.157	-0.230	0.170	-0.308	1

* and ** represent the significant level of 5% and 1%, respectively.

(ALI et al., 2022; ZHAO et al., 2019). In this study, 13 rice quality traits (including GL, GW, L / W, Tr, CGA, CD, GC, AC, AV, TV, BDV, SBV and CSV) were analyzed by PCA. The analysis showed that the variation coefficients of the four principal components were 82.478% (Tab. 3). The first principal component (PC1) accounted for 34.391%, which was much cooking and eating quality traits. However, PC2, PC3, and PC4 indicated a total contribution of 20.935%, 17.708%, and 9.31%, respectively (Tab. 3; Fig. 1). Therefore, it is necessary to pay attention to the varieties with slender grain shape and good cooking and eating quality in the process of rice breeding.

Cluster analysis of *indica* rice

Based on the 18 phenotypic traits of rice, cluster analysis indicated that the 30 *indica* rice could be divided into five categories (Fig. 2).

Tab. 3: Principal component analysis of 13 phenotypic traits of rice

Traits	PC1	PC2	PC3	PC4
Eigenvalue	5.270	2.457	1.747	1.248
Contribution rate (%)	40.542	18.903	13.435	9.598
Cumulative rate (%)	40.542	59.445	72.880	82.478
GL	-0.106	0.074	0.337	0.342
GW	0.018	0.05	0.503	-0.273
L/W	-0.116	-0.003	-0.183	0.537
Tr	-0.018	0.272	0.001	-0.292
CGA	0.019	0.331	-0.203	0.085
CD	-0.003	0.383	-0.076	-0.045
GC	-0.096	0.046	0.298	0.310
AC	0.153	-0.076	0.041	0.052
AV	0.125	-0.195	-0.092	0.018
TV	-0.159	-0.106	-0.008	-0.231
BDV	-0.168	-0.078	-0.123	-0.176
SBV	0.178	0.062	0.09	0.161
CSV	0.174	0.031	0.029	0.121

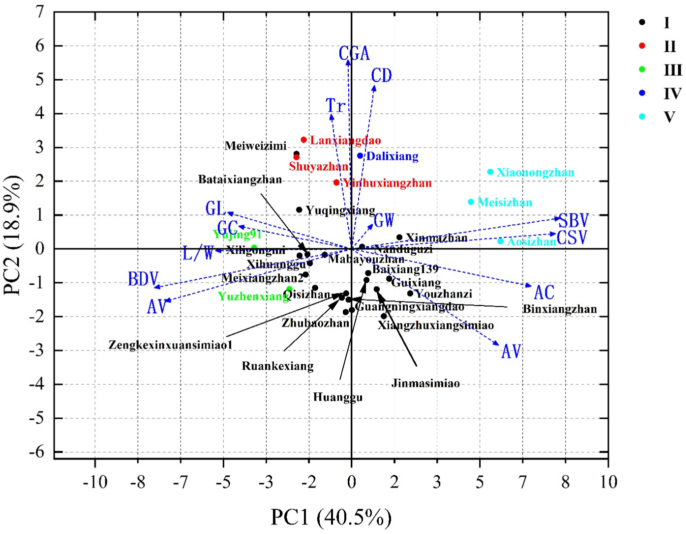

Fig. 1: PCA Bi-plot. Thirteen rice quality traits and their importance in 30 *indica* rice germplasms.

Category I was the largest, consisting of 18 varieties. Category II included three varieties: the Shuyazhan, Lanxiangdao, and Yinhuxiangzhan. Category III consisted of two varieties, namely the Yujing91 and Yuzhenxiang. Category IV had only one type, called the Dalixiang. Category V consisted of three varieties: the Meisizhan, Xiaonongzhan, and Aosizhan.

Evaluation was based on cluster analysis

The rice varieties of class I, II and III had long and slender grain shape, class IV had wide, and class V had short and small (Fig. 1A-C). We used five known molecular markers to reveal the grain shape regulators of 30 *indica* rice varieties The results showed that the grain size of most varieties was controlled by *GS3*, *GS9*, *GW5* and *GW8* genes. Small-grained Xinmazhan was the genotype of *gs3*. However, grain types in Xiangzhuxiangsimiao, Huanggu, Shuyazhan, Yuzhenxiang and Yujing91 were regulated by *GW7*, and their grain shape was slender (Fig. 4). In addition to grain type,

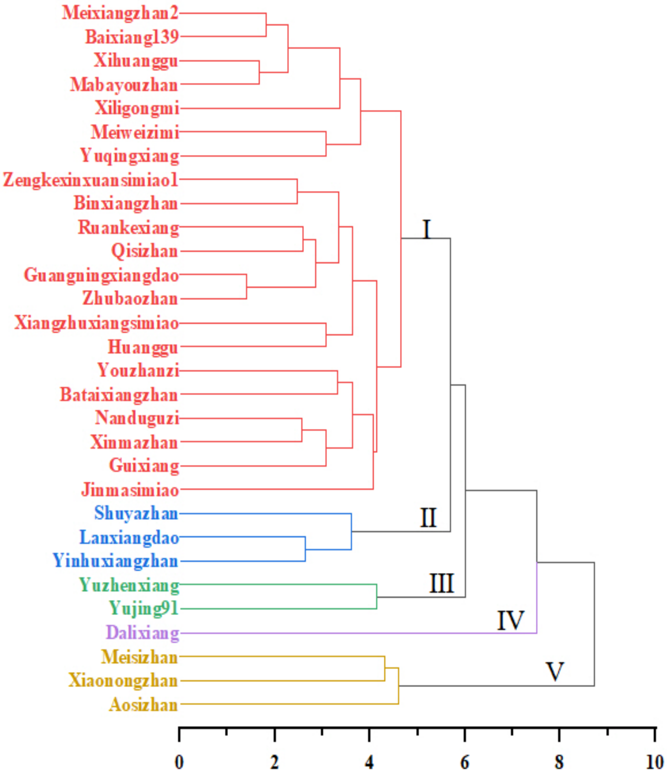

Fig. 2: Cluster analysis of 30 indica rice germplasms. Left are cultivar names. Cluster analysis is between groups method, measurement is squared Euclidean distance.

chalkiness is also an important trait of appearance quality. Less chalkiness and better transparency in I and III compared to II, IV and V (Fig. 5).

Cooking and Eating Quality is One of the Important Evaluation Indexes of Rice Quality. The difference in GC of these five types was slight, but the AC of class V was higher than that of other groups, resulting in higher AV and lower TV, thus affecting the cooking and eating quality of rice (Fig. 6A). *Wx* that controlling amylose content is the primary gene. We detected the *Wx* gene of 30 rice varieties revealing that most were Wx^b genotypes, and few were Wx^a genotypes (Fig. 6C).

Recently, RVA profile has gradually become an important evaluation index of rice quality. In these five categories, PV, PaT, and PeT difference is negligible. However, HPV, CPV, SBV, and CSV in category V were significantly higher than in the first four categories, and BDV was significantly lower than that in the first four categories (Fig. 6B).

Discussion

Effect of grain size on rice quality

Grain shape, closely related to other rice quality traits, is one of the crucial traits of rice quality. In the present study, we found that grain type had closely related to cooking and eating quality (Tab. 2). Grain shape is a quantitative trait controlled by multiple genes, more and more genes related to grain shape have been cloned (Fan et al., 2006; Wang et al., 2015; Wang et al., 2015; Tian et al., 2019). The genotypes of Xiangzhuxiangsimiao, Huanggu, Shuyazhan, Yuzhenxiang and Yujing91 were *GW7*, *GS3*, *GS9*, *GW5* and *GW8*, and their grain types were relatively slender. *GS3* negatively regulates grain size, *GS3* / *GW8* can make rice grain wider, *GS3* / *GS9* can make rice grain slender (Wang et al., 2012; Zhao et al., 2018). The genotype of Dalixiang was *GS3*/*GW8*, so its grain type was wide and larger. And The genotype of Zengkexinxuansimiao1 was *GS3*/*GS9*, and its grain type is slender (Fig. 4; Tab. 2).

The influence of AC on rice quality

Starch is the most abundant component in rice endosperm. However, amylose accounts for more than 90% of rice starch. There is a highly significant correlation between AC and cooking and eating quality traits (Tab. 2). As we all know, *Wx* is the main gene controlling amylose synthesis (Zhou et al., 2016; Teng et al., 2011). Due to the wide diversity of rice planting areas, the allelic variation of *Wx* gene contributed to regional AC differences and created taste

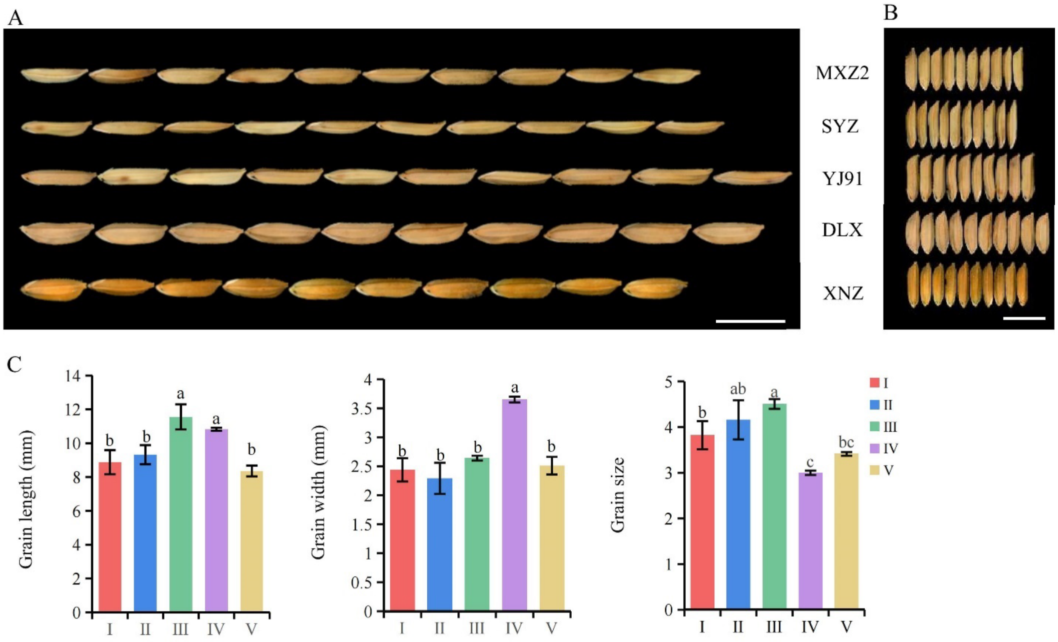

Fig. 3: Grain appearance. A, 10-grain length of five typical Varieties Based on Cluster Analysis; B, 10-grain width of five typical Varieties Based on Cluster Analysis; C, Statistical analysis of grain length, grain width, and grain size (length/width) Based on Cluster Analysis, Bar=10 mm

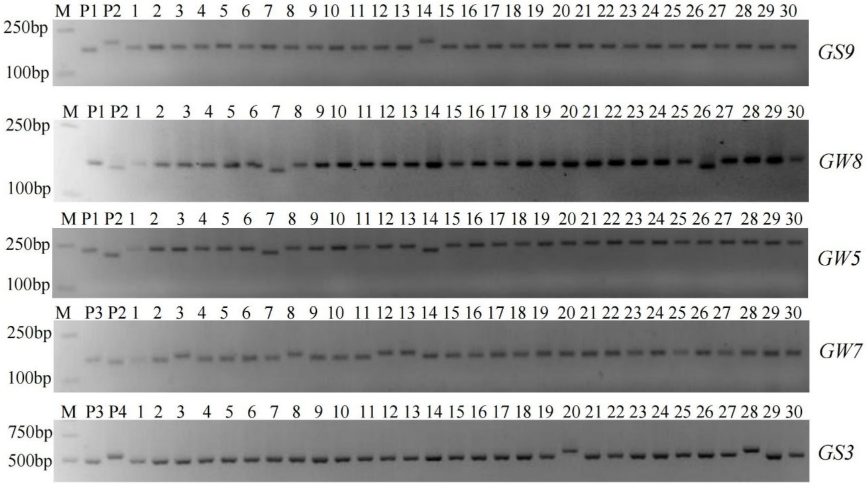

Fig. 4: Genotype of Grain Shape Genes. Electrophoresis pattern of test genotypes including resistant/tolerant check (P1 & P3) and susceptible check (P2 & P4) using grain shape genes (*GW7*, *GS3*, *GS9*, *GW5* and *GW8*) linked markers. M: marker (100-2000 bp); P1: Yuenongsimiao; P2: Lijiangxintuanheigu (LTH); P3: Xiangyaxiangzhan, P4: Yuexiangzhan.

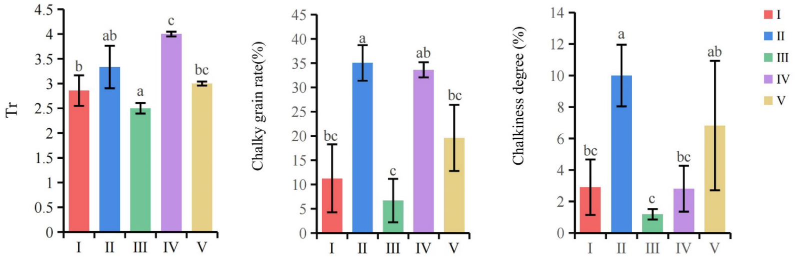

Fig. 5: Appearance Quality performance. Statistical analysis of chalky grain rate, Chalkiness degree and transparency(Tr) based on Cluster Analysis.

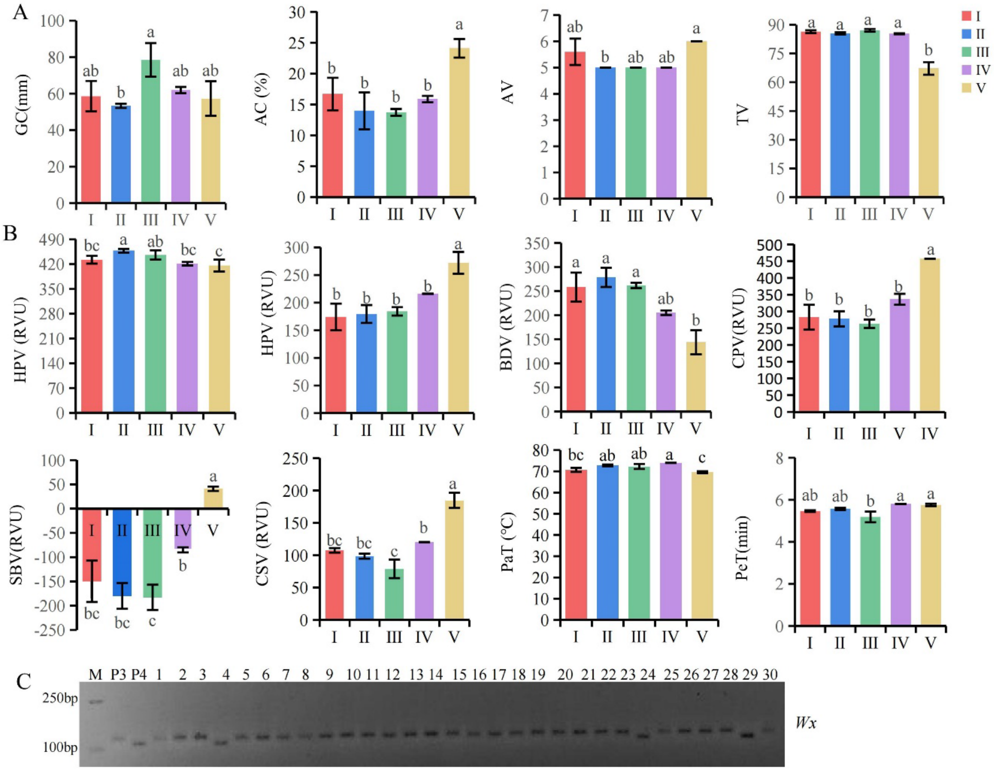

Fig. 6: Cooking and eating Quality performance. A, Statistical analysis of Gel consistency (GC), Amylose content (AC), Alkali value (AV), Taste value (TV) Based on Cluster Analysis; B, Statistical analysis of RVA spectrum characteristic values Based on Cluster Analysis. C, Electrophoresis pattern of test genotypes including resistant/tolerant check (P3) and susceptible check (P4) using *Wx* genes linked markers. M: marker (100-2000bp); P3: Xiangyaxiangzhan, P4: Yuexiangzhan.

preferences of people in different regions (Teng et al., 2011). This research showed that most rice varieties were Wx^{b} genotypes, and a few were Wx^{a} genotypes (Fig. 6C). However, in this study, Huanggu and Aosizhan had high amylose content but were not consistent with the genotype. In the allelic variation of *Wx* gene, Wx^{lv} is also related to high amylose content in addition to Wx^{a} (Zhou et al., 2021). Therefore, the genotypes of Huanggu and Ausizhan may be Wx^{lv}.

Effect of RVA profile on rice quality

There were highly significant correlations with each other RVA profiles, particularly the correlations among BDV, SBV, and CSV higher than 0.830 (Tab. 2). These results suggested that BDV, SBV, and CSV are important in RVA spectra. Previous studies showed that the characteristic values of the rice RVA spectrum, especially the BDV, SBV, and CSV, could better reflect the quality of rice cooking and eating (Fahad et al., 2016; Pang et al., 2016; Zhao et al., 2019). In this study, RVA spectrum, particularly BDV, SBV and CSV, had significantly correlated with cooking and eating quality of rice (Tab. 2). In the PCA, BDV, SBV and CSV and other cooking and eating quality traits were the first principal components, the contribution rate reached 40.542% (Tab. 3; Fig. 1). The cluster analysis showed that Class V was significantly lower than that of that of the first four categories in the BDV. Still, the SBV and CSV were considerly higher than those of the first four categories, resulting in the cooking and eating quality of the first four categories being better than that of the fifth category.

Breeding of high quality rice variety

In this study, 30 rice varieties had different quality traits. Breeders and researchers have cultivated many high quality rice varieties. The goal of rice breeding has gradually shifted from high-yielding to high-yielding and high-quality. The continuous advancement of molecular technology, molecular assisted breeding, molecular design breeding, and gene editing technology (such as CRISPR/Cas9) can accurately and effectively improve rice quality. Therefore, breeders and researchers can use and enhance advanced breeding techniques to cultivate high yield and quality new rice varieties.

Author contribution

FZ and HX designed the experiments and wrote the manuscript. FZ, LZ, and HX edited the manuscript. FZ, WS, LW, XJ and LD performed the experiments. FZ and WX analyzed the data. All authors contributed to the article and approved the submitted version.

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Conflict of interest

No potential conflict of interest was reported by the authors.

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Table S1 Rice quality traits of 30 *indica* rice varieties

Number	Accessiones	Origin	appearance quality						Eating and cooking quality traits				RVA spectrum characteristic values							
			GL	GW	L/W	Tr	CGA	CD	GC	AC	AV	TV	PV	HPV	BDV	CPV	SBV	CSV	PeT	PaT
1	Meixiangzhan2	Guangdong	8.19	2.28	3.81	3	8.76	1.30	67	14.35	5	87.80	441.63	140.50	301.13	242.21	-199.42	101.71	5.24	69.93
2	Meiweizimi	Guangdong	9.33	2.43	3.88	4	27.96	8.58	73	10.90	5	84.80	438.25	173.79	264.46	260.29	-177.96	86.50	5.40	71.45
3	Shuyazhan	Guangdong	9.11	2	4.65	4	34.98	8.93	54	15.28	5	84.60	460.59	161.13	299.46	253.04	-207.55	91.92	5.50	72.35
4	Meisizhan	Guangdong	8.53	2.53	3.42	4	18.74	3.37	68	23.85	6	70.70	412.71	249.42	163.30	448.04	35.34	198.62	5.70	69.85
5	Baixiang139	Guangxi	9.17	2.32	4.04	3	11.92	2.50	73	15.84	5	87.60	438.17	154.67	283.50	264.38	-173.79	109.71	5.33	70.70
6	Aosizhan	Guangdong	8.56	2.65	3.37	2	13.25	5.72	50	22.74	6	60.60	434.09	281.54	152.54	475.92	41.84	194.38	5.70	69.85
7	Zengkexinxuansimiao1	Guangdong	8.77	2.1	4.27	3	6.75	1.15	53	14.20	6	87.20	439.67	183.09	256.59	310.00	-129.67	126.92	5.54	70.65
8	Xiangzhuxiangsimiao	Guangdong	9.23	2.63	3.77	2	3.57	0.68	60	19.59	6	83.30	414.42	193.75	220.67	322.04	-92.38	128.29	5.64	69.85
9	Xiligongmi	Guizhou	9.72	2.43	4.19	3	12.56	3.45	65	18.85	5	91.10	423.46	133.42	290.04	227.63	-195.83	94.21	5.24	68.28
10	Yuqingxiang	Jiangxi	10.49	2.55	4.18	3	21.05	5.46	63	11.97	5	89.90	432.50	171.75	260.75	280.13	-152.38	108.38	5.47	70.75
11	Lanxiangdao	Hainan	9.96	2.53	3.98	3	38.74	12.26	54	10.54	5	86.50	461.21	185.17	276.05	283.79	-177.42	98.62	5.54	73.03
12	Yuzhenxiang	Hunan	11.03	2.61	4.43	2	3.52	0.95	72	13.33	5	86.40	436.63	178.84	257.80	272.29	-164.34	93.46	5.44	73.13
13	Yujing91	Hunan	12.08	2.67	4.58	3	9.85	1.42	85	14.13	5	87.80	455.34	189.58	265.75	254.21	-201.13	64.63	4.93	71.45
14	Dalixiang	Guizhou	10.83	3.65	3	4	33.62	2.81	62	15.88	5	85.30	421.25	216.04	205.21	336.34	-84.92	120.30	5.80	74.00
15	Youzhanzi	Guangdong	7.84	2.62	3.12	3	2.58	2.63	48	20.02	6	87.40	439.42	215.59	223.84	358.80	-80.63	143.21	5.73	71.55
16	Ruankexiang	Guangdong	8	2.35	4.02	3	6.54	2.18	55	17.65	6	87.00	442.13	164.04	278.08	262.42	-179.71	98.38	5.40	69.08
17	Guangningxiangdao	Guangdong	9.08	2.56	3.62	2	6.47	2.91	56	17.57	6	88.10	429.71	166.96	262.75	273.83	-155.88	106.88	5.44	69.83
18	Zhubaozhan	Guangdong	9.03	2.36	3.89	2	9.53	2.11	57	18.51	6	86.90	423.92	148.96	274.96	255.50	-168.42	106.55	5.33	69.85
19	Xihuanggu	Guangdong	9	2.57	3.56	3	10.18	2.26	67	16.56	5	88.80	444.21	155.46	288.75	247.71	-196.50	92.25	5.40	71.50

20	Mabayouzhan	Guangdong	7.95	2.38	3.36	3	11.96	3.89	60	15.50	5	88.00	441.17	163.92	277.25	253.00	-188.17	89.09	5.40	71.43
21	Yinhuxiangzhan	Guangdong	8.89	2.34	3.85	3	31.42	8.81	52	16.09	5	85.50	451.92	192.00	259.92	297.13	-154.79	105.13	5.67	73.08
22	Binxiangzhan	Guangdong	9.66	2.36	4.18	2	8.75	2.59	56	15.69	6	87.00	434.96	197.25	237.71	312.30	-122.67	115.05	5.60	71.45
23	Qisizhan	Guangdong	9.45	2.4	4	3	8.72	3.08	57	17.38	6	88.60	448.79	139.38	309.42	231.71	-217.09	92.33	5.17	70.65
24	Xiaonongzhan	Guangdong	7.99	2.35	3.45	3	26.81	11.37	54	25.71	6	70.30	401.04	285.55	115.50	446.96	45.92	161.41	5.87	69.08
25	Jinmasimiao	Guangdong	8.48	3	2.96	3	7.14	1.51	46	17.30	6	86.20	418.63	162.29	256.34	271.55	-147.09	109.26	5.47	71.45
26	Bataixiangzhan	Guangdong	8.12	2.36	3.53	3	6.54	0.71	46	16.47	5	80.20	439.00	197.83	241.17	313.71	-125.30	115.88	5.60	71.48
27	Nanduguzi	Guangdong	9.28	2.53	3.74	3	18.69	3.72	48	14.81	6	82.20	429.46	188.46	241.00	297.50	-131.96	109.05	5.73	71.53
28	Xinmazhan	Guangdong	7.83	2.19	3.65	3	26.53	3.63	46	17.71	6	79.30	417.80	199.42	218.38	323.04	-94.75	123.63	5.70	71.48
29	Huanggu	Guangdong	9.14	2.63	3.55	3	8.64	2.71	64	22.42	6	85.70	421.25	185.00	236.25	281.29	-139.96	96.29	5.47	71.45
30	Guixiang	Guangdong	8.66	2.15	4.1	3	7.54	2.54	44	17.29	6	83.70	409.09	208.96	200.13	336.29	-72.79	127.34	5.64	69.88
	Max		12.08	3.65	4.65	4	38.74	12.26	85	25.71	6	91.10	461.21	285.55	309.42	475.92	45.92	198.62	5.87	74.00
	Min		7.83	2.00	2.96	2	2.58	0.68	44	10.54	5	60.60	401.04	133.42	115.50	227.63	-217.09	64.63	4.93	68.28
	Average		9.11	2.48	3.81	2.99	14.78	3.84	58.51	16.94	5.56	84.26	433.41	186.12	247.29	299.77	-133.64	113.64	5.50	71.00
	Standard Deviation		0.99	0.29	0.42	0.52	10.27	3.05	9.59	3.49	0.47	6.40	14.68	36.12	44.37	61.65	70.06	28.69	0.20	1.30
	Coefficient of Variation (%)		10.85	11.77	11.13	17.39	69.52	79.40	16.38	20.58	8.49	7.60	3.39	19.41	17.94	20.57	-52.43	25.24	3.68	1.83

GL=Grain length (mm), GW=Grain width, L/W=Length width ratio, Tr=Transparency (livel), CGA=Chalky grain rate (%), CD=Chalkiness degree (%), GC=Gel consistency (mm), AC=Amylose content (%), AV=Alkali value (livel),TV=Taste value (point), PV=Peak viscosity (RVU), HPV=Hot paste viscosity (RVU), BDV=Breakdown viscosity (RVU), CPV=Cool paste viscosity (RVU), SBV=Setback viscosity (RVU), CSV=Consistence viscosity (RVU), PeT=Peak time (min), PaT=Pasting temperature (°C)