INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
17–1397/2018/20–5–959–965
DOI: 10.17957/IJAB/15.0583
http://www.fspublishers.org

Full Length Article

Comparisons of Plant-type Properties and Grain Quality in Filial Generations of Indica × Japonica Hybridization Grown in Different Rice-Growing Areas of China

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Abstract

The study aims to compare the grain quality traits in different ecological environments so as to find out how plant-type models and quality traits correlated in different environmental factors and to identify the differences among different plant types. Two populations of filial generations Indica × Japonica rice were grown in Sichuan and Liaoning. The processing quality, exterior quality, amylose content and taste score were significantly greater in Liaoning than Sichuan. However, there had less effect of ecological factors on protein content. The grain quality showed improving trend from low latitude characterized by shorter duration of sunshine, higher humidity and temperature to high latitude with better sunlight and temperature resources. Strong correlations existed between grain quality traits and certain plant-types. Moreover, the ecological environments have certain effects on the strengths and directions of these correlations. The erect-large panicle plant-type model with characteristics of short-flag-leaf, erect-panicle type had prominent performance in their milled and head rice rate in Sichuan. However, there had no significantly difference among different plant type model in Liaoning. The differences of exterior quality, nutritional quality and cooking and score quality among different plant type models were not significant, but regulated by the parental genotypes mainly under different rice-growing areas. © 2018 Friends Science Publishers

Keywords: Rice; Grain quality; Plant-type; Ecological environments; Ecotype environmental factors

Introduction

Rice is one of the leading food crops in the world, provides 35−60% energy for over three billion of the world's population and has become a major protein source of who take rice as staple food (Juliano, 1992; Fageria, 2007). However, the increasing population and economic growth lead to a rising demand for food, so rice production in the world has to achieve approximately 1% annual increase to meet the increasing demand (Rosegrant *et al*., 1995). Grain quality improving and ideal plant-type breeding were not only two mains aspect focused by breeding scientists (Hu *et al*., 2002; Chen *et al*., 2003), but also two difficult problems worth further study by rice breeders and cultivation experts from different regions in China (Chen *et al*., 1995; Cheng *et al*., 1995; Zhang *et al*., 2002). The breeding varieties developed with the approaches and theories of combination of plant-type improvement and the use of intersubspecific (indica/japonica hybrid) heterosis have been widely adopted for rice production. In the super hybrid rice breeding program, the main strategy was to combine the ideotype approach with the use of intersubspecific heterosis, with an aim to produce a super hybrid rice plant-type model (Yuan, 1997). Yang *et al*. (1996) stated that further increases in rice yield potential would have to come from the combination of plant-type improvement and the use of growth vigor and they proposed an erect-panicle plant type with is suitable for cultivation in areas with good weather during the filling phase. Zhou *et al*. (1995) developed a three line intersubspecific F1 hybrid between Indica and Japonica, this heavy-panicle plant-type is suitable for rice-growing areas with high humidity, high temperature, and limited solar radiation. Indica-japonica hybrids are known to show a very high level of heterosis for grain yield and creation of ideal plant type. The enormous number of mutations created by indica-japonica rice hybrids is an important means of the creation of ideal plant type, and there has close relationship between ecological environments and grain quality, Indica× Japonica subspecies (Wu *et al*., 2003; Xu *et al*., 2007; Mao *et al*., 2010; Jin *et al*., 2013a,b).

With the consumers becoming more concerned for the quality, emphasis on quality breeding has assumed a greater

To cite this paper: Jin, F., S. Hua, H. Xu, L. Yang, Y. Jiang, Z. Xu and X. Shao, 2018. Comparisons of plant-type properties and grain quality in filial generations of Indica×Japonica hybridization grown in different rice-growing areas of China. *Int. J. Agric. Biol*., 20: 959−965

significance in the recent years. The rice quality is determined by genotype, cultivation technique and ecological environments (Cheng *et al*., 2003; Sharifi *et al*., 2009; Sarah *et al*., 2011). The rice populations with ideal plant type model can comprehensive improved the plant population structure and light distribution, and so that it can increase the photosynthetic efficiency and dry matter accumulation capacity of rice, and it also has played important role in the improvement of rice grain quality (Zhang *et al*., 2002; Chen *et al*., 2008; Jin *et al*., 2008; Xu *et al*., 2008; Hao *et al*., 2010). Although many new plant types have been developed according to the previous studies on physiological ecology and yield capability (Khush, 1995; Yang *et al*., 1996; Yuan, 1997; Zhou and Liu, 1997; Huang, 2001), but a little information on the difference of rice quality traits and the interrelationship of rice quality characteristics with plant-type traits of indica-japonica hybrid rice has been reported, especially at different rice-growing areas. How to profound understanding of the relationship between ideal plant-type and grain quality of rice is one of the prerequisites for breeding rice variety with high-yield and high-quality using the theories of combine the ideotype approach with the use of intersubspecific heterosis in different environments. Therefore, to determine the influencing mechanism of ecological conditions on rice grain quality and plant-type characteristics and their correlations will offer scientific support for the future improvement of rice quality and ideotype breeding as well as take full advantage of the different regional ecological environments.

Taking two filial generations of Indica×Japonica rice hybrids as research materials, this study was respectively conducted in the southwest and northeast rice regions, which aims to: (I) determine the effects of environmental factors on grain quality and the relationships with plant type traits in China's different parts; (II) reveal the difference of grain quality in different plant type models.

Materials and Methods

In 2012, field experiments were carried out in the season of paddy growing. One was conducted from late April to mid-September in test site of Sichuan Agriculture Sciences Academy with located in Deyang, Sichuan province (N31º07′, E104º22′); the other was carried out from April to early October in Shenyang Agricultural University in Liaoning province (N41º80′, E123º44′). The soil from each base was compared based on FAO's classification method. The database of soil nutrient at Sichuan was Orthic Acrisols with pH7.6, total nitrogen 0.171%, total phosphorous 0.183%, total potassium 1.243% and organic carbon 24.8 kg^{-1}. The database of soil nutrient at Liaoning was Orthic Acrisols with pH 7.2, total nitrogen 0.120%, total phosphorous 0.159%, total potassium 3.126% and organic carbon 24.5 kg^{-1}.

The experimental materials were two RIL populations at F6 and F7 generations. The former, below known as the RILs-B(F6), was a hybrid of Shennong265 (Japonica with erect panicle) and Luhui99 (Indica with curved panicle); the latter, below known as the RILs-A(F7), was a hybrid of Japonica Liaogeng5 with erect panicle and Indica Wanlun422 with curved panicle.

In Liaoning, the sowing date and transplanting date were April 10 and May 15, and the seedlings spacing of row and plant were 30 cm and 13 cm, respectively. However, the dates of sowing and transplanting in Sichuan were April 20 and May 20, and the seedlings spacing of row and plant in Sichuan was accord with the spacing in Liaoning. In these two sites, the seedlings of per rice strain were transplanted 3 lines, 10 plants per line, and the every rice strain were arranged from highest to lowest based on the plant height of rice strain.

In the test site of Liaoning, we applied 150 kg N as urea ha^{-1}, 75 kg KCl ha^{-1} and 150 kg diammonium phosphate ha^{-1} one day before transplanting and 150 kg nitrogen topdressings as urea ha^{-1}seven days after transplanting. In brief, the amount of N, P_2O_5 and K_2O reached respectively to 165, 69, 45 kg ha^{-1} in the base of Liaoning. While in Sichuan, we applied 375 kg N like ammonium-bicarbonate ha^{-1}, 375 kg organic phosphate fertilizer ha^{-1}, and compound fertilizer of 375 kg ha^{-1} one day before transplanting and 112.5 kg nitrogen top dressings as urea ha^{-1} seven days after transplanting. In short, there was total 165 kg N, 82.5 kg P_2O_5 and 27 kg K_2O ha^{-1} in the base of Sichuan. In addition to this, there was no big difference in crop management and experimental methods between the two areas. Efforts were made in both sites to control weeds, insects and diseases to maximize crop yield.

The milling quality and appearance quality were measured according to national standard of the People's Republic of China (GB/17891-1999), after three months of harvest. Amylose content, protein content and taste score were measured by QS-4000 type high precision near infrared eating analyzer (shizuoka machine co., LTD production). 15-20 days after heading stage, we took five strains as samples and measured the plant height, flag leaf length, width and angle, panicle curvature, and length according to the description by Xu *et al*. (1990).

Two test sites were different in daily temperature, insolation duration, and daily average relative humidity at rice growing stage (Table 1). During the whole growing season in 2012, the daily average temperature in Sichuan was 23.40°C and Liaoning 19.68°C. The maximum temperature in Sichuan was obviously higher than that in Liaoning. From sowing to maturity, the average maximum temperature in Sichuan was 31.88°C and Liaoning 25.44°C. The average minimum temperature during this period was 17.96°C in Sichuan and 14.24°C in Liaoning. From sowing to maturity, the insolation duration in Liaoning was 7.49 h, two times of that of Sichuan (3.47 h). The relative humidity in Liaoning was lower in general

Table 1: Daily average, minimum and maximum temperature, insolation duration and average relative humidity for Sichuan and Liaoning in 2012

Growth stage	Region	
	Sichuan	Liaoning
Daily average temperature (°C)		
SS to HS [a]	22.66	20.00
HS to MS[b]	24.14	19.36
SS to MS[c]	23.40	19.68
Daily maximum temperature (°C)		
SS to HS[a]	30.86	25.53
HS to MS[b]	32.90	25.34
SS to MS[c]	31.88	25.44
Daily minimum temperature (°C)		
SS to HS[a]	16.45	14.30
HS to MS[b]	19.47	14.17
SS to MS[d]	17.96	14.24
Insolation duration (h)		
SS to HS[a]	3.11	7.57
HS to MS[b]	3.83	7.41
SS to MS[c]	3.47	7.49
c (%)		
SS to HS[a]	82.70	66.10
HS to MS[b]	85.14	79.18
SS to MS[c]	83.92	72.64

Each value shows the averaged value for each day during the period.[a] From sowing stage (SS) to heading stage (HS), average 95 days at Sichuan, 110 days at Liaoning. [b] From heading stage to maturity, average 60 days at Sichuan, 65 days at Liaoning. [c] From sowing stage to maturity, average 155 days at Sichuan, 175 days at Liaoning

than that in Sichuan, and this difference was showed more significant at early growth phase of rice.

We using analysis variance (ANOVA) to test the data difference between Sichuan and Liaoning. We conducted hierarchical cluster analyses using the between-groups linkage method. All the data statistical analyses were performed using SPASS (v18.0).

Results

Two RILs population's rate of brown rice, milled rice, head rice, amylose content and score in Liaoning was higher than that in Sichuan, among which the difference in milled rice rate, head rice rate, amylose content and score was especially significant. The chalky rice rate and chalkiness degree in Sichuan was higher than that in Liaoning in two populations, and the difference was significant. This indicated that environmental condition played a dominant role in determining the difference of these above quality traits in filial generations of Indica × Japonica hybrids, and its impact was significant. However, we also discover that protein content in two ecological regions showed difference between the two different populations. In RILs-A, it showed that Liaoning >Sichuan, while in RILs-B, it showed Sichuan was significantly higher than Liaoning. This finding indicated that it was hereditary factors rather than ecological environment that played a major role in the impact on protein content. Therefore, great consideration should be given to the local climate for refined quality of rice varieties in ideotype and cross breeding practice.

As shown in Table 2, grain quality was correlated with plant type traits under different ecological environments. In Sichuan, the brown rice rate was negatively correlated with plant height, with a significant correlation of RILs-A; but in Liaoning, there was a positive relationship between the brown rice rate and plant height and RILs-B had reached significant level. The directional correlation between brown rice rate and other plant type traits varied among different combinations of populations. The milled rice rate in Sichuan was negatively correlated with flag leaf curvature and RILs-B had reached significant level. The relationships among milled rice rate and plant height, panicle length, curvature of flag leaf and panicle were positive correlation, and in RILs-A had reached significant level. The level and direction of correlation among head rice rate and plant type traits changed in two RILs populations in different regions. This finding indicated that there was no direct relationship between milling rice rate quality and plant type, and genetype of parents played the major role in this relationship. Negative correlation between chalky grains and plant height was found in both regions and reached a significant level in RILs-A of Sichuan; While positive correlation between chalky grains and flag leaf length, panicle curvature, flag leaf curvature was found in Sichuan and reached a significant level in RILs-B. In Liaoning, chalky grains negatively correlated with panicle length, with a significant level in RILs-B. Chalkiness in Sichuan negatively correlated with plant height and showed significant level in RILs-A, and positively correlated with curvature of panicle, length and curvature of flag leaf, and showed significant level in RILs-B. Chalkiness showed negative correlation with panicle length, panicle curvature and flag leaf curvature, but the correlation significance varied with the populations in Liaoning. The protein content showed significant negative correlation with plant height in Sichuan, however positive with flag leaf curvature in Liaoning. Amylose content in Sichuan, was significantly correlated with plant height and panicle length, and positively correlated with the length of flag leaf and panicle, and plant height in Liaoning. The correlation among score and plant height, panicle length showed positive relationship in different region. Especially, in Sichuan has reached significant level. This finding indicated that there has a certain relation between rice grain quality and plant-type traits, and ecological condition exerts an impact on its correlative direction and degree to some extent.

A great quantity of lines made it difficult for us to analyze the plant type traits through multiple comparisons at different level of yield. So, we were conducted the hierarchical cluster analyses adapt to the methods of between groups linkage to classify the length of flag leaf for two RILs (Du *et al*., 2007). According to the data of flag length (Table 3), we were divided the flag leaves into long and short type. Specific criteria were as follows: for RILs-A, flag leaves longer than 33.73 cm were

Table 2: The correlation between plant type traits and grain quality under different environments

Traits	Region	Population	PH	PL	FLL	FLW	PC	FLC
BRR	Sichuan	RILs-A	-0.042	0.045	0.058	-0.049	0.091	-0.019
		RILs-B	-0.212*	-0.151	-0.092	0.021	-0.063	-0.162
	Liaoning	RILs-A	0.225*	0.168	0.038	-0.127	0.153	0.121
		RILs-B	0.100	0.022	0.024	0.023	0.078	0.152
MRR	Sichuan	RILs-A	-0.058	-0.008	-0.006	-0.141	0.061	-0.074
		RILs-B	-0.147	-0.072	-0.060	0.065	-0.046	-0.192*
	Liaoning	RILs-A	0.327**	0.214*	0.084	-0.152	0.155	0.210*
		RILs-B	0.088	0.047	0.042	-0.119	0.247**	0.106
HRR	Sichuan	RILs-A	-0.148	-0.083	-0.061	-0.083	-0.024	-0.005
		RILs-B	0.089	0.139	0.014	-0.010	-0.011	-0.09
	Liaoning	RILs-A	0.216*	-0.064	-0.088	-0.118	0.171	0.177
		RILs-B	-0.140	-0.122	-0.132	0.032	0.105	-0.184*
CG	Sichuan	RILs-A	-0.189*	-0.159	0.000	0.133	0.092	0.040
		RILs-B	-0.118	0.056	0.236**	0.004	0.339**	0.179*
	Liaoning	RILs-A	-0.070	-0.025	0.078	0.070	0.017	-0.088
		RILs-B	-0.042	-0.210*	-0.065	0.143	-0.104	-0.111
CHA	Sichuan	RILs-A	-0.253**	-0.233**	-0.065	0.121	0.077	0.069
		RILs-B	-0.081	0.022	0.160	0.051	0.278**	0.195*
	Liaoning	RILs-A	-0.094	-0.061	0.040	0.105	-0.018	-0.113
		RILs-B	0.014	-0.219*	-0.066	0.085	-0.079	-0.011
PT	Sichuan	RILs-A	-0.186*	-0.150	-0.175*	0.013	-0.077	-0.091
		RILs-B	-0.362**	-0.056	0.081	-0.235**	0.066	-0.004
	Liaoning	RILs-A	-0.100	0.036	0.081	-0.061	0.004	0.040
		RILs-B	0.047	0.049	0.051	0.030	-0.100	0.216*
AC	Sichuan	RILs-A	0.287**	0.316**	0.083	-0.152	-0.105	-0.055
		RILs-B	0.250**	0.055	-0.013	0.093	-0.050	-0.267**
	Liaoning	RILs-A	0.217*	0.479**	0.303**	-0.090	0.240*	0.118
		RILs-B	0.098	0.043	0.189*	0.099	-0.147	0.037
Score	Sichuan	RILs-A	0.356**	0.359**	0.268**	-0.147	0.086	0.109
		RILs-B	0.226**	0.103	-0.056	0.173*	-0.084	-0.076
	Liaoning	RILs-A	0.243**	0.173	0.066	-0.314**	0.140	0.071
		RILs-B	0.013	0.033	-0.101	-0.165	0.282**	-0.137

*and**：significant at the 0.05 and 0.01probability levels, respectively. BRR: Brown rice rate; MRR: Milled rice rate; HRR: Head rice rate; CG: Chalky grains; CHA：Chalkiness; PT: protein content; AC: Amylose content. PH: plant high; PL: Panicle length; FLL: Flag leaf length; FLW: Flag leaf width; PC: Panicle curvature; FLC: Flag leaf curvature

Table 3: The cluster analysis of Flag leaf length

Group	Average / cm	CV/ %	Range/ cm	Number	Frequency/ %
	RILs-A				
Length	39.95	11.21	33.86-54.86	307	52.93
Short	28.09	15.03	15.92-33.73	273	47.07
	RILs-B				
Length	42.43	13.54	35.28-63.9	168	33.14
Short	27.63	15.65	15.08-35.16	339	66.86

classified as long, and those shorter than 33.73 cm were classified as short; for RILs-B, this value was 35.16 cm. Panicle were divided into erect and curved depended on the angle of curvature (Xu *et al*., 2010). Panicle with a curvature angle less than or equal to 50º were classified as erect, and those with a curvature angle greater than 50º were classified as curved. Plants were classified into four types according to flag leaf length and panicle curvature: short flag leaf, curved panicle (Sc); short flag leaf, erect panicle (Se); long flag leaf, curved panicle (Lc); and long flag leaf, erect panicle (Le).

We compared grain quality traits among different plant type models under different environments (Table 4). In Sichuan, the rate of brown rice, milled rice and head rice of Le were the lowest and those traits of Se were greater than those of the other plant type models expect for brown rice rate in RILs-A, but the difference was not so significant. Little difference was found in the rate of brown rice and milled rice in Liaoning among different plant-type models; the head rice rate of Le in Liaoning was lower than other plant-type model, and there was no obvious difference among others. The Chalky grains of Se in RILs-A was lower than other plant-type models between Sichuan and Liaoning; as to Chalkiness, it showed the following trend: Le>Lc>Sc>Se; For RILs-B, the Chalky grains and Chalkiness showed the following trend: Le>Sc>Se>Lc in Liaoning, the trend was Lc>Sc>Se>Le in Sichuan; the difference between the highest and lowest reached significant level. Protein content of Sc in Liaoning and Le in Sichuan were the lowest. No obvious regularity was found

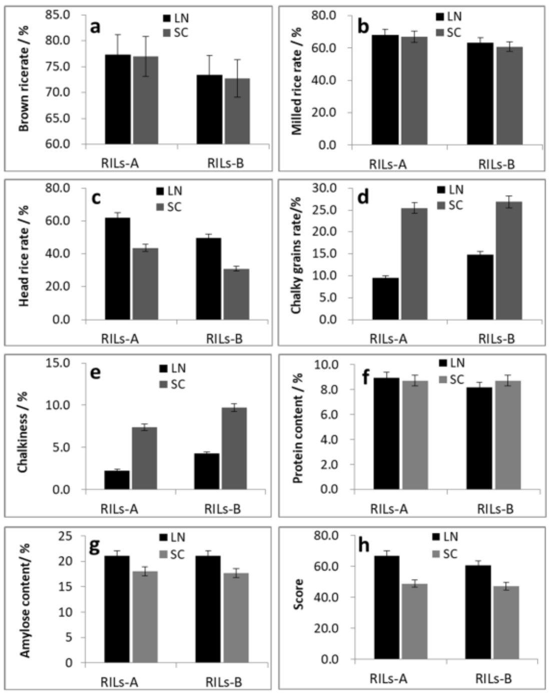

Fig. 1: The difference of grain quality under different environments LN: Liaoning; SC: Sichuan

about the difference of the amylose content and Score in both regions among different plant-type models (Fig. 1).

Discussion

The rice quality was influenced significantly by ecological environments (Lin *et al*., 2005; Zhu *et al*., 2009). Yang *et al*. (2006) found that head rice rate, chalky grains and chalkiness of hybrid rice varieties had greatly changed under different ecological regions grown and grain filling duration's daily average temperature was the controlling factor for that changes. Ambardekar *et al*. (2011) Sarah *et al*. (2011) also found that during critical grain-filling periods, the increase of nighttime air temperatures had a great influence on chalk formation and milling quality of field-grown rice. The rise of CO_2 could be good for protein content decreasing; however, that was against the raise of processing quality, especially milled rice rate (Yang *et al*., 2007). Our research found that the rate of brown rice, milled rice and head rice, amylose content and taste score were significantly greater in Liaoning than Sichuan; the chalky grains and chalkiness in Liaoning was significantly lower than in Sichuan. This indicated that ecological environment conditions had a significant influence on rice quality in filial generations of Indica × Japonica hybrids. There is a trend of improvement from low latitudes with high temperatures, high humidity and short day to high latitudes with better photosynthesis-temperature resource.

Analyses of reasons indicated that the daily average temperature, the lowest and the highest temperature in Liaoning were greatly lower than that in Sichuan; in addition, the longer insolation duration, lower daily average relative humidity, and higher diurnal temperature at the grain filling stage in northern China were the main ecological factors contributing to the grains filling rate and filled-grain percentage (include grain weight and seed setting rate) in Liaoning. Lin *et al*. (2005), Yang *et al*. (2006) have already made similar findings. The improvement of rice quality in Liaoning may have benefited from local physiological and ecological conditions. We also found that protein content in different ecological environment regions was significantly different in the two populations; in RILs-A, it showed a trend of Liaoning>Sichuan and for RILs-B, it showed Sichuan was greatly higher than that in Liaoning. This finding indicated that the ecological environments had an insignificant effect on protein content (Cheng and Zhong, 2001), while hereditary factors played the major role. Therefore, in breeding, we should firstly determine the influencing mechanism of ecological environments on rice quality characteristics in particular area and then selecting according to their parents.

Previous studies have reported the relationships between rice grain quality and plant-type traits which covered the correlation among grains quality and plant-type traits, yields and cultivated conditions. (Cheng and Zhong, 2001; Zhao *et al*., 2003; Wang *et al*., 2005; Xu *et al*., 2007; Zhu *et al*., 2009; Hao *et al*., 2010; Mao *et al*., 2010; Jin *et al*. 2013a,c). However, for the lack of comprehensive evaluation and comparable analysis of ecological environments influence on relationships between grain quality and plant-type traits in filial generations of Indica×Japonica crosses, and combined with the complexity of the quality traits response to climate conditions, there is still no clear understanding on it up to now.

Taking two filial generations of Indica × Japonica rice hybrids as research subjects, the study made a comprehensive analysis of the relationships between rice quality and plant-type traits. The results indicated that there were certain relationships between rice quality and plant-type traits and ecological environments had significantly affected the correlative direction and level. It also indicated that in the breeding practice of different rice regions, the rice eating quality could be improved by appropriate increase in the plant height and panicle length; especially in Liaoning (northeast of China), which also was conducive to improvement of the processing quality. The appearance and nutrient quality of rice could be improved by appropriate decrease in the flag leaf length and decrease in the flag width in Liaoning. There has a certain relation between panicle-type and plant-type traits (Xu *et al*., 2007; Chen *et al*., 2008; Jin *et al*., 2008).

After researching on the filial generations Indica×Japonica rice hybrid, we find that appropriate

Table 4: The difference of grain quality traits in different plant type

		RILs-A				RILs-B			
		Sc	Se	Lc	Le	Sc	Se	Lc	Le
BRR / %	Liaoning	78.32a	76.99a	76.93a	77.74a	73.55a	73.35a	73.69a	73.24a
	Sichuan	77.25a	76.68a	77.54a	75.64a	72.69a	73.03a	72.59a	69.79b
MRR /%	Liaoning	69.74a	67.74a	67.69a	68.34a	64.27a	62.17a	63.03a	62.22a
	Sichuan	67.06a	66.96a	66.90a	66.54a	60.60a	61.39a	60.76a	57.74a
HRR / %	Liaoning	64.97a	61.94a	63.54a	60.69a	51.00ab	49.28a	49.16a	35.14a
	Sichuan	41.31a	45.56a	42.87a	41.81a	29.07a	32.19a	31.60a	28.02a
CG / %	Liaoning	8.60b	8.39b	11.75a	11.64a	15.34b	14.46b	7.43c	25.75a
	Sichuan	28.70a	25.60a	24.70a	23.47b	29.95ab	19.87b	36.20a	15.00c
CHA / %	Liaoning	2.08a	2.08a	2.25a	2.66a	4.65ab	3.88ab	1.80b	6.90a
	Sichuan	8.93a	7.81a	6.89a	5.37a	11.2a	7.14b	12.71a	5.75b
PT / %	Liaoning	8.15a	8.25a	8.20a	10.63a	8.10a	8.26a	8.41a	8.13a
	Sichuan	8.76a	8.78a	8.66a	8.66a	8.73a	8.72a	8.77a	8.37b
AC / %	Liaoning	21.39a	20.78a	20.93a	21.47a	20.69b	21.20b	21.64b	23.35a
	Sichuan	17.95b	17.99b	17.94b	18.84a	17.91a	17.56a	17.55a	18.82a
TS	Liaoning	69.32a	65.96a	71.03a	67.04a	65.08a	56.71ab	58.71a	44.68b
	Sichuan	46.44b	45.22b	51.97ab	55.01a	48.16ab	47.18ab	45.02b	55.85a

Means followed by a different capital letter within a column is significantly different at the 0.05 probability levels
BRR: Brown rice rate; MRR: Milled rice rate; HRR: Head rice rate; CG: Chalky grains; CHA: Chalkiness; PT: protein content; AC: Amylose content;TS: Taste score

decrease in panicle curvature could increase the appearance quality in Sichuan, Southwest of China and increase the milled rice rate and Score in Liaoning, Northeast of China. Sichuan, Southwest in China, should select the genetic strains with erect flag leaf and small angle in order to facilitate the improvement of processing quality and appearance quality, but this relationships was not significant in Liaoning. According to our results, we believe that the relationship between rice quality and plant-type traits was affected not only by ecological environments, but also by genetic factors. Therefore, in breeding practice, high-quality rice cultivars and the plant-type models should be chosen in view of the correlation of rice quality and plant type characteristics in order to cultivate ideal rice varieties and plant type suitable for local ecological conditions.

There were some differences of rice quality traits among different plant types. Jin *et al*. (2008) reported that varieties with curvature panicle performed better in brown rice, milled rice and head rice rate as well as grain weight than the varieties with erect panicle. Xu *et al*. (2007) also founded that the varieties with heavy panicle type and dense panicle type could help to rise of rice yield, but not benefit to improve of rice quality. The processing quality, appearance quality and Score of varieties with erect panicle were better than that variety with heavy panicle type and dense panicle type.

The appearance quality of rice showed the maximum variant extent, while that of milling quality is the minimum, and other quality traits showed intermediate level of variant in filial generations of erect-panicle plant type varieties × curvature-panicle plant type varieties crosses; The milling quality and appearance quality of erect-panicle varieties always showed lower than that of curvature-panicle varieties (Wang *et al*., 2005). Little research has been done so far on the variations of rice quality traits of different plant-type models grown in diverse ecological environments.

Our research finding showed that the short-leaf and erect-panicle plant type (Se) had higher milled and head rice rate than other plant type models in Sichuan, the southwest of China; the difference of brown rice rate and head rice rate among different plant-type models in Liaoning, northeast of China, was less significant. All these indicated that the plant type with short leaf and erect panicle (Se) showed better grain processing quality in Sichuan, southwest of China while there were less significant differences among plant-type models in Liaoning, the northeast of China, which is consistent with the results of my earlier study(Jin *et al*., 2008). Further analysis of the results showed the appearance quality, nutritional quality, cooking quality has less significant difference among different plant-type models in different ecological environments, and these differences were mainly regulated by the parental genotypes.

Conclusion

The results showed that grain quality were significantly improved from low latitude to high latitude; the improvement of rice quality in northeast of China, may have benefited from local physiological and ecological conditions. There were certain relationships between rice quality and plant-type traits and ecological environments had significantly affected the correlative direction and level. The plant type with short leaf and erect panicle (Se) showed better grain processing quality in southwest of China.

Acknowledgments

The research was founded by National Key Research and Development Program of China (2016YFD0300104, 2017YFD0300609, 2016YFC0501204), National Natural

Foundation of China (31371587), and Programs for Science and Technology Development of Jilin Province (20160204011NY).

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(Received 11 December 2017; Accepted 06 January 2018)