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Study of combining ability and gene action of cooking quality traits in rice (*Oryza sativa* L.) using line × tester analysis

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Abstract

The relative proportion of additive and non-additive genetic variances in a population can be used as a tool to study inheritance of traits. This research was an attempt to estimate the combining ability and action of genes associated with the cooking quality of rice. Four lines (restorer) and three testers (male sterile line) were crossed to obtain twelve F1 hybrids in a line × tester fashion at Rice Research Institute of Amol, Iran in 2010. In the 2011growing season, parents and hybrids were laid out in a randomized complete block design with five replications. After harvesting, seeds were characterized for amylose content (AC), gelatinization temperature (GT) and gel consistency (GC). In the present study, the analysis of variance for general combining ability (GCA) and specific combining ability (SCA) were significant for the traits with the exception of SCA variance for GT. The GCA effect was larger than the SCA effect for GT while the AC and GC had larger SCA. These results along with calculation of predictability factor revealed that traits AC and GC were governed by genes with dominance action while additive gene action was more important in the genetic control of GT.

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Introduction

Rice (*Oryza sativa* L.) has a special place in the feeding of Asian societies. However, rice cooking quality has a direct impact on consumer preference and thus sales and consumption of this product. Researches show, cooking quality of rice is related directly to the physical and chemical characteristics of endosperm starch including amylose content (AC), gelatinization temperature (GT) and gel consistency (GC).

Amylose content determines cooked rice texture. Rice varieties with low AC become very sticky, moist and tender on cooking, whereas varieties with intermediate AC become fluffy, soft, moist and tender and those with high AC become fluffy and dry and harden on cooling (Kumar and Khush, 1987).

Gelatinization is the peak temperature at which starch absorbs. GT is important because it affects the texture of cooked rice and it is said to be related to the cooking time of rice (Cuevas *et al.*, 2010).
Gel consistency as a measure of cold paste-viscosity of cooked milled rice flour is a good index of cooked rice texture. Rice differs in GC from soft to hard. Cooked rice with hard GC hardens faster than that with a soft one (Tang *et al.*, 1991).

To maintain and transfer desirable traits of cooking quality, rice breeders are looking for the most suitable parental combination. In this way, combining ability provides an important tool for selection of desirable parents and to get required information on gene action controlling desirable trait (Rastogi *et al.*, 2011). Different mating systems have been purposed to study and evaluate combining ability in genetic researches. Although the diallel crosses have been applied in breeding programs however, it requires a large workforce especially when the number of genotypes increases. Therefore, Kempthorne (1957) suggested line × tester technique as a faster method for estimating combining ability and screening suitable lines for hybridization. Since then, many researchers have practiced line × tester analysis over hybrid rice genotypes (Patil *et al.*, 2012; Raju *et al.*, 2012; Saidaiah *et al.*, 2011; Singh and Sharma, 2007; Tiwari *et al.*, 2011). The purposes of this research were to evaluate combining ability and gene action of traits related to cooking quality among hybrid rice varieties.

Materials and methods

Four restorer lines/male IR56, IR28, IR59606-119-3 and SA13 along with three male sterile lines/female Neda, Nemat and IR58025 were grown at Rice Research Institute, deputy of Mazandaran province, Amol, Iran, (36°, 28' N and 52°, 23' E, with altitude of 29.8 m above the sea level) in 2010 and crossed in a line × tester mating system design. In the next growing season (2011), single seedlings of twelve obtained F_1 hybrids along with their parents were planted with space of 20 × 20 cm in a randomized complete block design with five replications. At harvest time, seeds were collected and analyzed for AC, GT and GC according to the methods suggested by Juliano (1971), Little *et al* (1958) and Cagampang *et al* (1973), respectively. The mean squares from line × tester design and the GCA and SCA variances and effects were calculated according to the procedures developed by Kempthorne (1957). Mean comparisons were conducted using Tukey method at 0.05 level of probability. Calculations were carried out using Microsoft excel 2007, SAS version 9.2 and Mstat-C.

Results and discussion

Analysis of variance revealed significant differences among genotypes ($p<0.01$) for all traits (Table 1) which implied genetic variation existed for studied traits. Coefficient of variation was varied from 3.15 for AC to 9.88 for GT indicating appropriate precision of the experiment. The highest broad sense heritability belonged to GC (95.2%) while GT (75.6%) had the lowest (Table 1).

Selection for AC and GT will have low efficiency with regards to the low expected genetic advance calculated for these traits (5.91 and 1.90, respectively). Differences due to lines as well as testers were not significant for AC and GC while, line by tester interaction had significant effect on both traits.

Amylose Content

Amylose content is considered to be the key determinant of the processing, cooking and eating characteristics of rice and it correlates directly with the volume expansion, water absorption and ultimate firmness of cooked rice (Juliano, 1985). In this study, among parents, the AC was varied from 25.54% for IR58025 to 32.14% for SA13. Also hybrids Neda/IR56 and IR58025/IR28 had the highest (31.68%) and lowest (23.43%) AC values, respectively (Table 2).
Both GCA and SCA effects were significant for AC indicating the importance of both additive and non-additive gene action in the genetic control of this trait (Table 2). This result was in agreement with findings of Singh *et al.* (1977); McKenzie and Rutger (1983); Pooni *et al.* (1993); Tan *et al.* (1999); Asfaliza *et al.* (2012) and Gnanamalar and Vivekanandan (2013).
Female Nemat with 1.85 and IR56 with 1.73 had the highest GCA effects and hence were the best general combiners for AC. The deviation of the predictability factor (PF=0.28) from 0.50 suggests the relative predominance of non-additive over additive effects in the genetic control of this trait (Table 3). Also, Table 3 shows that the σ^2SCA was greater than σ^2GCA and the proportion of dominance component was more than the additive component. Therefore dominance gene action had more importance in the genetic control of AC. Therefore, the narrow sense heritability was low and thus, selection should be postponed to later generations from the segregating population.

Table 1. Line × tester analysis of variance of traits related to cooked rice quality among seven parents and related twelve F_1 hybrids.

Source of variation	D.F	mean square		
		AC	GT	GC
Treatment (Genotype)	18	104.80**	13.82**	5402.90**
Parents	6	82.95**	18.97**	7207.50**
Parents × Crosses	1	188.53**	0.54 n.s	1464**
Crosses	11	109.30**	12.20**	4776.50**
Lines	3	94.07 n.s	37.10**	5982 n.s
Testers	2	197.40 n.s	5.65 n.s	8223 n.s
Line × Tester	6	87.60**	1.96**	3026**
Error	209	0.48	0.36	22.27
Proportion in total variance %				
Lines		23.43	82.84	34.16
Testers		32.83	8.40	31.13
Line × Tester		27.06	8.78	34.56
C.V %		3.15	9.88	7.31
Total mean		21.99	6.10	64.60
Genotypic variance		8.69	1.12	448.40
Phenotypic variance		9.17	1.48	470.70
Broad scenes heritability %		94.7	75.6	95.2
Expected genetic advance%		5.93	1.88	42.46

AC, amylose content; GT, gelatinization temperature; GC, gel consistency
** means the mean square was significant at 0.01 level of probability and n.s means non-significant
C.V, coefficient of variation.

Gelatinization Temperature

The gelatinization temperature mainly affects the texture of cooked rice and thus cooking time of rice. Hence, breeding GT of rice would help reduction of worlds' fuel consumption (Cuevas *et al.*, 2010). Analysis of variance showed that testers didn't have significant effect on GT while, the effects of lines as well as line × tester interaction were significant. Among parents, the highest GT observed for IR58025. Also IR5906-119-3 with 3.33 showed the poorest GT. Hybrids Nemat/IR28 and Neda/IR5906-119-3 had the highest (6.83) and lowest (4) GT, respectively (Table 2).

Table 2. General and specific combining ability and means of traits related to cooked rice grain quality estimated over seven parents and related twelve F_1 hybrids.

Parents/Hybrids		AC (%)		GT		GC (mm)	
		Mean	CA	Mean	CA	Mean	CA
Testers/Females	A1	29.91 c	0.32**	6.50 a	-0.40**	43.5 fgh	-6.42**
	A2	31.89 a	1.85**	6.50 a	0.21*	46.0 efg	-8.63**
	A3	25.54 g	-2.16**	6.83 a	-0.19*	95.0 a	15.04**
Lines/Males	R1	32.14 a	1.73**	6.75 a	0.58**	91.0 ab	0.30**
	R2	30.26 bc	0.73**	6.75 a	0.63**	86.5 bc	7.82**
	R3	28.24 d	-0.43**	3.33 d	-1.51**	75.0 d	8.19**
	R4	26.09 fg	-2.03**	6.50 a	0.30**	38.5 h	-19.01**
Hybrids	A1×R1	31.68 a	2.35**	6.50 a	0.26 n.s	49.00 ef	-10.24**
	A1×R2	29.45 c	1.12**	6.75 a	0.45**	49.08 ef	-14.99**
	A1×R3	25.38 g	-1.78**	4.00 cd	-0.16 n.s	80.92 cd	16.48**
	A1×R4	23.87 h	-1.69**	5.42 b	-0.55**	46.00 efg	8.75**
	A2×R1	31.26 a	0.42*	6.58 a	-0.26 n.s	51.92 e	-5.12**
	A2×R2	31.15 ab	1.29**	6.67 a	-0.24 n.s	75.08 d	13.22**
	A2×R3	27.41 de	-1.28**	5.00 b	0.24 n.s	49.17 ef	-13.06**
	A2×R4	26.67 ef	-0.43*	6.83 a	0.26 n.s	40.00 gh	4.96**
	A3×R1	24.06 h	-2.78**	6.83 a	0.01 n.s	96.08 a	15.36**
	A3×R2	23.43 h	-2.41**	6.67 a	-0.21 n.s	87.33 bc	1.78 n.s
	A3×R3	27.75 d	3.08**	4.67 bc	-0.08 n.s	82.50 c	-3.41*
	A3×R4	25.21 g	2.12**	6.83 a	0.29 n.s	45.00 fgh	-13.72**

Grouping was applied using Tukey method (α=0.05).

Means that do not share a letter are significantly different.

AC, amylose content; GT, gelatinization temperature; GC, gel consistency; CA,combining ability

A1, Neda; A2, Nemat; A3, IR58025;

R1, IR56; R2, IR28; R3, IR59606-119-3; R4, SA13

* and ** means the mean square was significant at 0.05 and 0.01 level of probability respectively, and n.s means non-significant.

Because of the highest GCA effects, IR28 was the best general combiner while, IR5906-119-3 showed a low GCA. The proportion of testers in total variance was less than proportions of lines as well as line × tester. This result revealed that the male parent was responsible of a great proportion of the variation in the GT variation (Table 1). Therefore, the possibility of cytoplasmic influence on GT expression was very poor. This result was in agreement with Tan *et al.* (1999) and Cuevas *et al.* (2010) observations.

The SCA effects were not significant except for Neda/SA13 and Neda/IR28 (Table 2) which implies the poor role of dominance gene action in the genetic control of this trait. Also, the proportion of additive component of genetic variance (σ^2A=0.92) was larger than dominance component (σ^2D=0.13). Moreover, the PF factor was about 0.87 which suggests predominance of additive over dominance effects (Table 3). According to these results, additive gene action had more importance in the genetic control of GT and thus GT's narrow sense heritability would be high. Therefore selections can effectively be performed in early generations. Faruq *et al* (2004) and Kiani *et al.* (2008) reported same results. However Chen *et al.* (1992) reported that GT inheritance is determined by one of two dominant genes and affected by modifying factors. Recently Liu *et al.* (2013) reported that both epistatic effect and additive effect had equal importance in inheritance of GT.

Table 3. Values of GCA and SCA variances estimated through line × tester analysis of traits related to cooked rice quality among seven parents and related twelve F_1 hybrids.

Trait	σ^2_{GCA}	σ^2_{SCA}	σ^2_A	σ^2_D	PF
AC	1.38	7.26	2.77	7.26	0.28
GT	0.46	0.13	0.92	0.13	0.87
GC	56.61	344.68	113.22	344.68	0.25

AC, amylose content; GT, gelatinization temperature; GC, gel consistency; Pf, Predictability factor.

Gel Consistency

Rices differ widely in the rate of hardening of cooked rice and differences in hardness of cooked rice correlate with differences in GC (Cagampang *et al.*, 1973). In this study the highest and lowest GC values were observed in parents IR58025 (95 mm) and SA13 (38.5 mm), respectively. Also hybrids, Neda/IR5906-119-3 and Nemat/IR28 had the highest (96.08 mm) and lowest (40 mm) mean values (Table 2).

Table 4. Pearson's Correlation coefficients between cooked rice quality traits and corresponding combining ability estimated among seven parents and related twelve F_1 hybrids.

	GCA effects				SCA effects		
Trait mean in Parents	AC	GT	GC	Trait mean in Hybrids	AC	GT	GC
AC	0.997**			AC	0.662*		
GT		0.872*		GT		0.297	
GC			0.880**	GC			0.588*

** and * mean correlation is significant at the 0.01 and 0.05 levels of probability, respectively (2-tailed).

A high GCA effect was recorded for IR58025 (15.04) while, the lowest GCA effect belonged to SA13 (-19.01). The SCA effect was significant for all crosses (p<0.01) except for IR58/IR28. Crosses Neda/IR58025/IR5906-119-3 with 16.48 and Neda/IR28 with -14.99 showed the highest and lowest values of SCA effects.

Studies over inheritance of gelatinization temperature were inconsistent in respect of the nature of dominance-recessive relationship (Faruq *et al.*, 2004).

In this research, both GCA and SCA effects were significant for GC showing the importance of both additive and non-additive gene action for the genetic control of this trait (Table 2). However, the SCA effects were significant except for IR58025/IR28 (Table 2) which implies the privileged role of dominance gene action in the genetic control of GC. Likewise AC, the deviation of PF from 0.50 (0.25) suggested the relative predominance of non-additive over additive effects in the genetic control of GC (Table 3). With regard to Table 3, the σ^2SCA (344.68) was greater than σ²GCA (56.61). According to these results, GC is controlled by more influence of dominance effect and thus its narrow sense heritability is low.

Significant positive correlations were observed between mean performance of studied traits and corresponding GCA effects (Table 5). Likewise, among hybrids, mean performance of traits AC and GC were correlated with corresponding SCA effects while GT didn't show this correlation which confirms the importance of additive gene action in the genetic control of GT.

Conclusion

Estimation of GCA and SCA effects showed that the inheritance of AC and GC were the same. Both were under influence of dominance gene action and had poor heritability. Therefore, selection is better to be postponed to later generations from the segregating population. Also methods based on recurrent selection will show better response. On the other hand, additive gene action had more importance in the genetic control of GT and with regard to the high heritability of GT, selection would have a suitable genetic worth in early generations.

References

Asfaliza R, Rafii MY, Saleh G, Omar O, Puteh A. 2012. Combining ability and heritability of selected rice varieties for grain quality traits. Australian Journal of Crop Science **6,** 1718-1723.

Cagampang GB, Perez CM, Juliano BO. 1973. A gel consistency test for the eating quality of rice. Journal of the Science of Food and Agriculture **24,** 1589-1594.

Chen BT, Peng ZM, Xu YQ. 1992. Genetic analysis of ricegelatinization temperature. Journal of Huazhong Agricultural University. **11,** 115-119.

Cuevas RP, Daygon VD, Corpuz H, Nora L, Reinke R, Waters D, Fitzgerald M. 2010. Melting the secrets of gelatinization temperature in rice. 28th International Rice Research Conference, Hanoi, Vietnam.

Faruq G, Hadjim KMO, Meisner CA. 2004. Inheritance of gelatinization temperature in rice. International journal of agriculture & biology **6,** 810-812.

Gnanamalar RP, Vivekanandan P. 2013. Combining ability analysis of grain quality traits in rice (*Oryza sativa* L.). Asian Journal of Plant Science and Research **3,** 145-149.

Juliano BO. 1971. A simplified assay for milled rice amylose. Cereal Science Today **16** 334-338.

Juliano BO. 1985. Criteria and Test for Rice Grain Quality, in: Champagne ET, ed. Rice Chemistry and Technology, American Association of Cereal Chemists, St. Paul, MN, USA. 443-513 p.

Kempthorne O. 1957. An introduction to genetic statisticsed. John Wiley & Sons, Inc., New York.

Kiani S, Ranjbar GA, Kazemitabar SK, Jelodar NB, Nowrozi M, Bagheri N. 2008. Inheritance of gelatinization temperature and gel consistency in rice (*Oryza sativa* L.). Journal of Applied Sciences **8,** 1503-1510.

Kumar I, Khush GS. 1987. Genetic analysis of different amylose levels in rice. Crop Science **27,** 1167-1172.

Little RR, Hilder GB, Dawson EH. 1958. Differential effect of dilute alkali on 25 varieties of milled white rice. Cereal Chemistry **35,** 111-126.

Liu Qm, Jiang Jh, Niu Fa, He Yj, Hong Dl. 2013. QTL Analysis for seven quality traits of RIL population in japonica rice based on three genetic statistical models. Rice Science **20**.

McKenzie KS, Rutger JN. 1983. Genetic analysis of amylose content, alkali spreading score, and grain dimensions in rice. Crop science **23** 306-313.

Patil VA, Vashi RD, Patil PP, Shinde DA. 2012. Line × tester analysis in rice (*Oryza sativa* L.). Plant Archives **12** 463-469.

Pooni HS, Kumar I, Khush GS. 1993. Genetical control of amylose content in a diallel set of rice crosses. Heredity **71** 603-613.

Raju CHD, Krishna L, Raju CHS, Vanisree S, Reddy PN, Reddy BB. 2012. Ggene action and combining ability for quantitative traits in rice (*Oryza sativa* .L). Research Journal of ANGRAU **40,** 60-68.

Rastogi A, Mishra BK, Srivastava M, Siddiqui A, Shukla S. 2011. Biplot approach foridentification of heterotic crosses in linseed (*Linum usitatissimum* L.). Journal of Botany **11,** 1-7.

Saidaiah P, Ramesha MS, Sudheer Kumar S, Suresh J. 2011. Combining ability analysis for yield and yield component traits in rice (*Oryza sativa* L.). Journal of Reserach ANGRAU **39,** 28-33.

Singh NB, Singh HG, Singh P. 1977. Heterosis and combining ability for quality components in rice. Indian Journal of Genetics Plant Breeding **37,** 347-352.

Singh SKHB, Sharma JK. 2007. Combining ability analysis for grain yield and other associated traits in rice. Oryza **44,** 108-114.

Tan YF, Li JX, Yu SB, Xing YZ, Xu CG, Zhang Q. 1999. The three important traits for cooking and eating quality of rice grains are controlled by a single locus in an elite rice hybrid, Shanyou 63. Theoretical and Applied Genetics **99,** 642-648.

Tang SX, KHUSH GS, Juliano BO. 1991. Genetics of gel consistency in rice (*Oryza sativa* L.). Journal of Genetics **70,** 69-78.

Tiwari DK, Pandey P, Giri SP, Dwivedi JL. 2011. Nature of gene action and combining ability for yield and its related traits in hybrid rice. Oryza **48,** 288-296.