Research Article

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Effect of Different Transplanting Time on Cooking and Milling of Some Fine and Coarse Grain Rice Genotypes

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Abstract

In order to elucidate the effects of transplanting date on grain shape, appearance, cooking, milling and eating quality traits of nine coarse grain and ten fine grain indica rice lines under four sowing date treatments were studied. The main results showed that the effects sowing date and cultivars on the grain qualities were highly significant. Delayed sowing date, milling quality, total and head rice recovery, cooked grain length and bursting percentages showed different trend with respect to the rice lines. However in case of fine grain rice lines, head rice recovery decreased at last transplanting date. Cooked grain length and head rice recovery increased whereas bursting percentage decreased in fine grain lines with delaying sowing date. However, in coarse type, bursting percentage decreased drastically and became stable after second date of transplanting. In case of cooked grain length in coarse type rice lines, it remained stable at all the dates. Brown rice percentage and total milling recovery were significantly different among different sowing dates with little change. Earlier or much delayed sowing or transplanting would result in the degradation of taste value as well as head rice recovery. The response of different traits to the site and sowing date was different. The stability of various quality traits for different cultivars varied with the transplanting time. KSK 133 and Basmati 515 showed maximum head rice recovery among coarse and fine grain rice lines respectively. Likewise, PK 8785-1-1 and PK 8671-24-4-1-20 showed maximum cooked grain length among coarse and fine grain rice lines respectively.

Keywords: Milling, Cooking, Quality traits, fine grain, coarse grain, rice lines.

Introduction

Rice is an important food crop of world and feeds almost half of the world's population. Rice in Pakistan holds an extremely important position in agriculture and the national economy. Pakistan is the world's 11th largest producer of rice, after China, India, Indonesia, Bangladesh, Vietnam, Thailand, Burma, Philippines, Brazil and Japan. Rice is the second largest staple food crop and is also an exportable item. It accounts for 3.2 percent in the value added in agriculture and 0.7 percent of GDP. During July-March 2014-15, rice export earned foreign exchange of US$ 1.53 billion. During 2014-15, rice was sown on an area of 2891 thousand hectares showing an increase of 3.6 percent over last year's area of 2789 thousand hectares. Rice recorded highest ever production at 7005 thousand tonnes, showing a growth of 3.0 percent over corresponding period of last year's production which was 6798 thousand tonnes. (Economic Survey of Pakistan 2014-15). Rice is grown in all five provinces of Pakistan, its mainland is plain areas of Province Punjab. Pakistan stands among the leading exporters of rice in the world, and is known for its cooking quality i-e longer grain length special taste and aroma, which can be produced nowhere else but in "Kallar Track" of Pakistan.

Kallar Track in an area in Punjab which includes District Sialkot, Narowal, Gujaranwala, Hafizabad, Shiekhupura and some part of District Lahore. Due to the presence of heavy clay soil enriched with calcium carbonate the trait of aroma can only be expressed in this soil. Pakistani basmati rice is a source of foreign exchange earning More than 1.36 million tonnes of rice worth $507 million were exported in the 2014-15 fiscal year (Ministry of Commerce Pakistan). Being an agrarian based economy, Pakistan's economic growth depends upon progress in agricultural research. In rice sector, there is only one known public sector rice research institution in Pakistan: Rice Research Institute, Kala Shah Kaku. While conducting research on rice many management practices are adopted to check the effect on its quality and production.

Transplanting date is a key factor which affects quality of basmati and coarse grain rice cultivars. To acquire higher paddy yield of better quality, coarse grain varieties may be transplanted from mid-June to early July. Pakistani farmers are demanding superior rice grain quality varieties for different reasons [1-3]. The of rice grain quality parameters includes many components such as appearance, cooking, milling and eating qualities. Among these, consumers

often pay more consideration to appearance after cooking [4]. Genetic and environmental factors both confer great effect on rice grain quality, especially photo-periodism and temperature at the heading and doughing stage. There are increase chances of occurrence of chalky grain and reduction of the head rice ratio because of high temperature during the heading stage [5,6]. The optimum temperature to produce superior quality rice is about to be 25°C at the filling stage [7]. The reason for deterioration of rice quality is because of the high temperatures at grain filling and doughing stage adversely affect kernel development and reduce the carbohydrates in the plant, leading to a decrease in the head rice recovery as well as cooking traits [8-10].

The grain dimensions of both paddy and milled rice was affected by sowing and transplanting date. Bran percentage was significantly increased with late transplanting dates, however decrease in amylose content occur. Late transplanting dates affect the cooking time as it decrease the cooking time but increased the solid losses in gruel. Similarly late transplanting deteriorated the organoleptic features of cooked rice and had higher values for clearing and spreading [11]. Different rice varieties showed Significant variation in rice quality characters (head rice and broken) tested under different transplanting dates [12]. For this reason, it is necessary to evaluate the performance and quality characteristics of rice cultivars/promising lines at different transplanting dates in order to measure the effect of high temperature and photo-sensitive during the ripening stage.

Material and Methods

Research study was carried out in Rice Technology section of Rice Research Institute, Kala Shah Kaku where grain shape, appearance, cooking, milling and eating quality traits of rice breeding material comprising of nine coarse grain and ten fine grain indica rice lines transplanted under four transplanting date treatments were studied. Physical characteristics include milling recovery (Brown Rice, Total Milled Rice and Head Rice percentages) and cooking quality (Cooked Grain Length and percentage of grains bursting upon cooking).

The objective of this experiment is to ascertain the optimum time (date) of transplanting for obtaining higher milling recovery and best cooking quality in advanced coarse grain rice lines. There were eight advance coarse grain lines and nine fine grain lines including two check varieties from each group of grain type transplanted at four different dates by the Agronomy Section of this institute. Transplanting dates were kept in the main plots while varieties / lines in sub plots. After harvesting from the field, paddy samples were cleaned, dried to 10 % moisture content and milled in the Rice Technology Laboratory. The data on milling recovery and cooking quality of these lines were determined and compared with standard check variety of KSK 133 (coarse grain type) and Basmati 515 (fine grain type).

Results and Discussion

The main results showed that the effects sowing date and cultivars on the grain qualities were highly significant. Delayed sowing date, milling quality, total and head rice recovery, cooked grain length and bursting percentages showed different trend with respect to the rice lines. However in case of fine grain rice lines, head rice recovery decreased at last transplanting date. Cooked grain length and head rice recovery increased whereas bursting percentage decreased in fine grain lines with delaying sowing date. However, in coarse type, bursting percentage decreased drastically and became stable after second date of transplanting. In case of cooked grain length in coarse type rice lines, it remained stable at all the dates. Brown rice percentage and total milling recovery were significantly different among different sowing dates with little change. Earlier or much delayed sowing or transplanting would result in the degradation of taste value as well as head rice recovery. The response of different traits to the site and sowing date was different. The stability of various quality traits for different cultivars varied with the transplanting time.

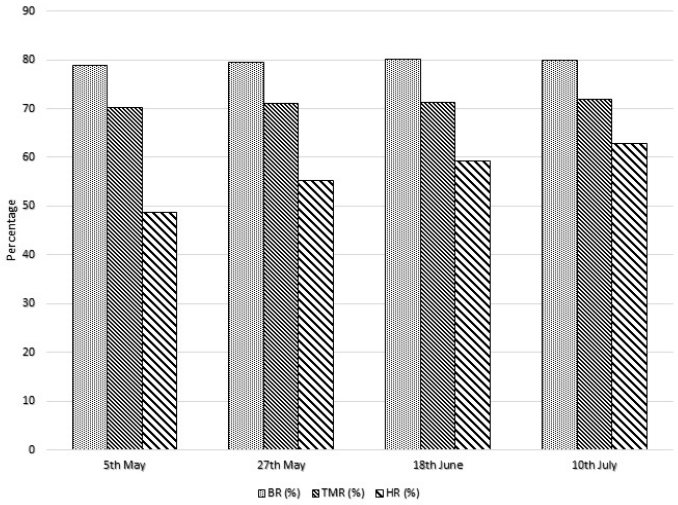

Figure 1: Changes in average brown rice, total milling recovery and head rice recovery percentages of coarse grain rice lines due to changing transplanting dates.

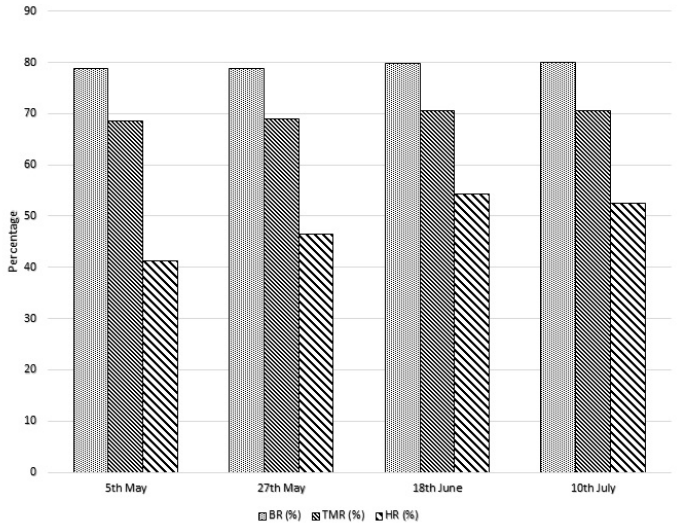

Figure 2: Changes in average brown rice, total milling recovery and head rice recovery percentages of fine grain rice lines due to changing transplanting dates.

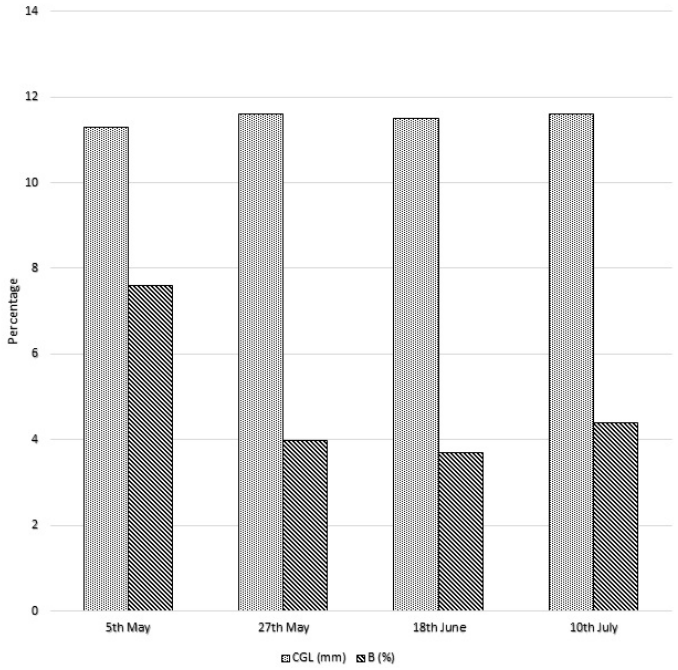

Figure 3: Changes in average cooked grain length and bursting percentages of coarse grain rice lines due to changing transplanting dates.

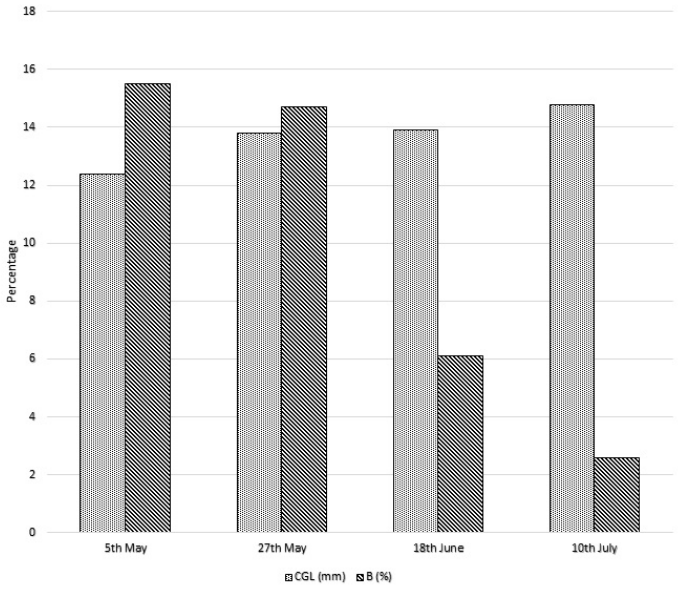

Figure 4: Changes in average cooked grain length and bursting percentages of fine grain rice lines due to changing transplanting dates.

The above table 1 shows that on average with respect to date of transplanting, maximum brown rice (79.1%) and maximum total milled rice (71.3%) were recorded at transplanting date of 14th July 2014 followed by date 5th August 2014 with 79.0% BR, 71.3% TMR. Maximum Head Rice (59.2%) was recorded at transplanting date of 5th August 2014 followed by 14th July 2014 with 54.4% HR. Taking average data with respect to lines, maximum TMR (73.6%) was observed for line PK 8662 followed by line PK 8971-24-3-1-19 with 71.8% TMR. Similarly on average, maximum HR% of 65.6% was observed for line PK 8662 followed by line PK 8971-24-3-1-19 with 57.9% HR. Individually, maximum HR% of 67.0% was observed for line PK 8662 on 5th August followed by line PK 8971-24-3-1-19 with 64.0% HR at the same transplanting date. Overall, best milling recovery was observed at transplanting date of 5th August followed by 14th July.

The above table 3 shows that on average with respect to date of transplanting, maximum cooked grain length (CGL) of 15.9 mm was recorded for transplanting date 5th August 2014 followed by transplanting date 14th July 2014 with 15.1 mm CGL and 6.1 % bursting percentage. With respect to average data of lines, maximum CGL of 16.3 mm was observed for line RRI-7 with 7.8 % bursting. On average minimum bursting o 6.1% was observed at 14th July 2014 and for individual line minimum bursting of 3.3% was observed for line 10052. As for individual performance, maximum CGL of 18.0 mm was recorded for line RRI-7 with 3.0% bursting at transplanting date of 5th August followed by line PK PB 4 with 17.2 mm CGL and 10.0% bursting at the same transplanting date. In all, best cooking quality was recorded at transplanting date of 5th August followed by 14th July. Lines RRI-7 and PK PB 4 performed well.

The results in table 2 shows that on average with respects to date, maximum brown rice (80.3%) was recorded at transplanting date of 18th August 2014 followed by date 10th August 2014 with 79.9% BR. Similarly, maximum TMR (71.3%) was observed transplanting date of 18th August 2014, followed by transplanting date of 27th May 2014. Maximum head rice of 62.8% was observed on transplanting date of 10th July 2014 followed by transplanting date of 18th August 2014 with 59.4% HR. With respect to average data of lines, maximum TMR% of 72.0% was observed for line KSK 469 followed by line PK 7688-1-1-2-2 with 71.9% TMR. Similarly, maximum HR % of 59.8% was observed for line KSK 474 followed by line PK 8785-1-1 with 58.2% HR which is below the HR% of standard check variety of KSK 133 with 62.0% HR. However, overall line KSK 474 give better result in milling recovery as discussed above.

The table 4 shows that on average with respect to date of transplanting, maximum cooked grain length of 11.6 mm with minimum bursting percentage of 4.0% was recorded for transplanting date 27th May 2014 followed by transplanting date 10th July 2014 with 11.6 mm CGL and 4.4% bursting. On average data with respect to lines/variety, maximum CGL of 12.9 mm was observed for line PK 8785-1-1 with 5.0 % bursting followed by line PK 7688-1-1-2-2 with 12.8 mm CGL and with 1.5% bursting which is also a minimum. Individually, maximum CGL of 13.6 mm with 5.0% bursting was recorded for line PK 8785-1-1 on 10th July 2014 followed by line PK 7688-1-1-2-2 with 13.2 mm CGL with 0.0% bursting on 27th May 2014. In all, best cooking quality was recorded at 27th May and 10th July and by the lines PK 7688-1-1-2-2 and PK 8785-1-1 performing well as discussed above.

Date	5th May 2014			27th May 2014			18th June 2014			10th July 2014			Average		
Line/Variety	BR (%)	TMR (%)	HR (%)	BR (%)	TMR (%)	HR (%)	BR (%)	TMR (%)	HR (%)	BR (%)	TMR (%)	HR (%)	BR (%)	TMR (%)	HR (%)
PK 8662	81.0	74.0	66.0	81.0	74.0	66.0	78.5	74.5	63.5	79.5	72.0	67.0	80.0	73.6	65.6
PK 8971-24-3-1-19	78.0	69.0	50.0	79.0	71.0	56.0	81.0	74.0	61.5	79.0	73.0	64.0	79.3	71.8	57.9
PK 8971-24-4-1-20	78.5	68.0	39.0	76.5	68.0	39.0	78.5	71.0	51.0	80.0	72.0	62.5	78.4	69.8	47.9
PK 9118	78.0	68.0	31.0	77.5	69.0	42.5	81.0	74.0	62.0	80.5	73.0	65.0	79.3	71.0	50.1
10052	78.0	68.0	31.0	76.0	68.0	46.0	79.5	73.5	58.0	80.0	72.0	64.0	78.4	70.4	49.8
PK PB 4	76.0	68.0	30.0	77.0	69.0	40.0	77.0	68.0	48.0	78.0	68.5	51.5	77.0	68.4	42.4
PK 8431	76.0	68.0	35.0	80.0	69.5	43.0	80.0	70.0	51.0	79.0	71.5	55.0	78.8	69.8	46.0
RRI 7	76.0	68.0	15.0	76.0	69.5	29.0	77.0	70.0	40.0	76.0	68.5	44.5	76.3	69.0	32.1
Average	77.7	68.9	37.1	77.9	69.8	45.2	79.1	71.9	54.4	79.0	71.3	59.2	_	_	_

Table 1: Brown rice, total milling and head rice recovery of different fine grain rice lines. BR = Brown rice, TMR = Total milled rice, HR = Head rice.

Date	1st June 2014			23rd June 2014			14th July 2014			5th August 2014			Average		
Line/Variety	BR (%)	TMR (%)	HR (%)	BR (%)	TMR (%)	HR (%)	BR (%)	TMR (%)	HR (%)	BR (%)	TMR (%)	HR (%)	BR (%)	TMR (%)	HR (%)
KSK 133 (Check)	78.0	70.0	54.0	80.0	72.0	66.0	80.0	72.0	65.0	80.0	72.0	62.0	79.8	69.5	48.9
KSK 449	80.0	72.0	41.5	79.0	71.0	54.0	79.5	70.5	51.0	79.5	74.0	64.0	79.5	70.9	55.3
KSK 466	80.0	71.5	37.0	77.5	71.5	60.0	76.5	69.5	53.5	81.0	70.5	55.6	80.8	72.1	63.5
KSK 473	78.0	71.5	41.5	78.0	71.5	65.0	80.5	70.5	60.0	80.5	72.0	62.0	80.1	71.9	59.5
KSK 474	81.0	71.5	54.5	79.0	72.0	62.0	81.0	69.5	55.5	81.5	73.0	57.0	79.3	70.1	45.6
PK 7688-1-1-2-2	80.0	72.0	50.0	79.0	73.0	68.0	80.0	69.5	55.5	80.5	72.0	61.0	79.5	68.8	40.9
PK 8785-1-1	79.0	71.5	54.0	80.0	72.0	65.5	79.0	73.0	64.0	81.5	73.0	55.0	78.6	68.9	42.8
PK 9118-2-3-3-1-1-19	80.0	71.5	51.0	77.0	71.0	64.5	78.0	72.0	66.5	81.0	72.0	66.0	78.6	68.0	39.6
Average	78.8	68.7	41.3	78.8	69.1	46.6	79.9	70.6	54.3	80.0	70.7	52.5	_	_	_

Table 2: Brown rice, total milling and head rice recovery of different coarse grain rice lines; BR = Brown rice, TMR = Total milled rice, HR = Head rice.

Date	5TH May 2014		27th May 2014		18th June 2014		10th July 2014		Average	
Line/Variety	CGL (mm)	B (%)	CGL (mm)	B (%)	CGL (mm)	B (%)	CGL (mm)	B (%)	CGL (mm)	B (%)
PK 8662	14.8	11.0	14.5	10.0	14.6	7.0	14.4	4.0	14.6	8.0
PK 8971-24-3-1-19	12.3	10.0	12.7	7.0	14.0	9.0	15.2	6.0	13.6	8.0
PK 8971-24-4-1-20	14.8	2.0	14.5	3.0	14.3	5.0	16.0	6.0	14.9	4.0
PK 9118	13.0	25.0	13.5	15.0	14.7	12.0	15.2	7.0	14.1	14.8
10052	13.0	5.0	13.2	2.0	14.5	3.0	15.0	3.0	13.9	3.3
PK PB 4	14.6	22.0	14.0	21.0	16.2	6.0	17.2	10.0	15.5	14.8
PK 8431	12.9	4.0	12.5	5.0	15.2	2.0	16.0	19.0	14.2	7.5
RRI 7	15.0	13.0	14.7	10.0	17.5	5.0	18.0	3.0	16.3	7.8
Average	13.8	11.5	13.7	9.1	15.1	6.1	15.9	7.3	-	-

Table 3: Cooked grain length and bursting parameters of different coarse grain rice lines; CGL = Cooked Grain Length; B = Bursting upon cooking.

Date	1st June 2014		23rd June 2014		14th July 2014		5th August 2014		Average	
Line	CGL (mm)	B (%)	CGL (mm)	B (%)	CGL (mm)	B (%)	CGL (mm)	B (%)	CGL (mm)	B (%)
KSK 133 (Check)	12.0	14.0	12.3	3.0	12.2	10.0	12.4	5.0	14.2	2.0
KSK 449	10.5	12.0	10.0	5.0	10.6	4.0	12.8	8.0	13.3	7.3
KSK 466	11.4	10.0	10.6	5.0	11.3	9.0	13.4	4.0	14.2	6.0
KSK 473	11.3	9.0	11.0	6.0	12.1	7.0	12.5	2.0	13.5	8.8
KSK 474	10.0	3.0	9.3	3.0	9.3	6.0	10.4	6.0	13.8	6.8
PK 7688-1-1-2-2	13.0	5.0	12.0	4.0	12.6	3.0	12.2	7.0	15.0	1.5
PK 8785-1-1	12.3	11.0	11.5	4.0	12.5	5.0	12.8	6.0	13.8	5.0
PK 9118-2-3-3-1-1-19	13.2	3.0	12.5	3.0	12.6	5.0	14.0	3.0	13.5	4.5
Average	12.4	15.5	13.8	14.7	13.9	6.1	14.8	2.6	-	-

Table 4: Cooked grain length and bursting parameters of different fine grain rice lines; CGL = Cooked Grain Length; B = Bursting upon cooking.

Conclusion

The results showed that the effects sowing date and cultivars on the grain qualities were highly significant. Delayed sowing date, milling quality, total and head rice recovery, cooked grain length and bursting percentages showed different trend with respect to the rice lines. However in case of fine grain rice lines, head rice recovery decreased at last transplanting date. Cooked grain length and head rice recovery increased whereas bursting percentage decreased in fine grain lines with delaying sowing date. However, in coarse type, bursting percentage decreased drastically and became stable after second date of transplanting. In case of cooked grain length in coarse type rice lines, it remained stable at all the dates. Brown rice percentage and total milling recovery were significantly different among different sowing dates with little change. Earlier or much delayed sowing or transplanting would result in the degradation of taste value as well as head rice recovery. The response of different traits to the site and sowing date was different. The stability of various quality traits for different cultivars varied with the transplanting time. KSK 133 and Basmati 515 showed maximum head rice recovery among coarse and fine grain rice lines respectively. Likewise, PK 8785-1-1 and PK 8671-24-4-1-20 showed maximum cooked grain length among coarse and fine grain rice lines respectively [13-31].

References

1. Yoshinobu T, Nonoue Y, Ebitani T, Suzuki K, Aoki N, et al. (2007) QTL detection for eating quality including glossiness, stikiness, taste and hardness of cooked rice. Breeding Sci 57: 231-242.
2. Hao W, Zhu MZ, Gao JP, Sun SY, Lin HX (2009) Identification of quantitative trait loci for rice quality in a population of chromosome segment substitution lines. J Integr Plant Biol 51: 500-512.
3. Lee JH, Cho JH, Kim SY, Lee JY, Kim CS, et al. (2012) Correlation analysis between head rice ratio and agronomic traits in RILs for developing a promising rice cultivar adaptable to the early-transplanting cultivation. Korean J Crop Sci 57: 1-6.
4. Guo T, Liu XL, Wan X, Weng J, Liu S, et al. (2011) Identification of a stable quantitative trait locus for percentage grains with white chalkiness in rice (Oryza sativa L.). J Intergr Plant Biol 53: 598-607.
5. Lisle AJ, Martin M, Fitzgerald MA (2000) Chalky and translucent rice grains differ in starch composition and structure and cooking properties. Cereal Chem 77: 627-632.
6. Adoration PR, Hara T, Julino BO, Yoshida S (1977) Effect of temperature during ripening on grain quality of rice. Soil Sci Plant Nutr 23: 109-112.
7. Jin ZX, Qian CR, Yang J, Liu HY, Jin XY (2005) Effect of temperature at grain filling stage on activities of key enzymes related to starch synthesis and grain quality of rice. Rice Sci 12: 261-266.
8. He GC, Kogure K, Suziki H (1990) Development of endosperm and synthesis of starch in rice grain III Starch property as affected by the temperature during grain development. Japan J Crop Sci 59: 340-345.
9. Morita S (2008) Prospect for developing measures to prevent high-temperature damage to rice grain ripening. Japan J Crop Sci 77: 1-12.
10. Morita S, Nakano H (2011) Nonstructural carbohydrate content in the stem at full heading contributes to high performance of ripening in heat-tolerant rice cultivar Nikomaru Crop Sci 51: 818-828.
11. Yawinder SS, Nagi S, Sidhu KS, Sekhon (2012) Physicochemical, milling and cooking quality of rice as affected by sowing and transplanting dates. J Sci Food Agric 37: 881-887.
12. Nishimura M, Kaji R, Ogawa T (2000) Varietal difference in the occurrence of coarse grain due to the high temperature stress given during the ripening period of rice plant. Breeding Res 2: 17-22.
13. Aboubacar A, Moldenhauer K, McClung AM, Beighley DH, Hamaker BR (2006) Effect of growth location in the United States on amylose content, amylopectin fine structure, and thermal properties of starches of long grain rice cultivars. Cereal Chem 83: 93-98.
14. Choi HC, Chi JH, Lee CS, Kim YB, Cho SY (1994) Varietal and locational variation of grain quality components of rice produced in hilly and high altitude areas in Korea. Korean J Crop Sci 39: 27-37.
15. Choi WY, Nam JK, Kim SS, Lee JH, Kim JH, et al. (2005) Optimum transplanting date for production quality rice in Honam plain area. Korean J Crop Sci 50: 435-441.
16. Choung JI, Kim KY, Choi YH, Ko JC, Oh MK, et al. (2004) Analysis of chemical and eating quality character of the early rice variety at cultured in the southern plain area. Korean J Intl Agri 16: 345-349.
17. Fujii Y, Mitsukawa M, Sakanashi J, Ueno I, Izumi K, et al. (2009) Breeding and characters of a new cultivar 'Kumasannochikara' with resistance to high-temperature during ripening period. Res Bull Kumamoto Pref Agric Res Cent 16: 1-10.
18. Ishima T, Taira H, Taira H, Mikoshiba K (1974) Effect of nitrogenous fertilizer application and protein content in milled rice on olganoleptic quality of cooked rice. Report of National Food Res Inst 29: 9-15.
19. Juliano BO, Onate LU, Mundo AM (1965) Relations of starch composition, protein content and gelatinization temperature to the cooking and eating quality of milled rice. Food Technol 19: 1006-1011.
20. Kohei T, Ryoki O, Masayuki M, Yushi I, Takashi Y, et al. (2009) Changes in NMR relaxation of rice grains, kernel quality and physicochemical properties in response to a high temperature after flowering in heat-tolerant and heat-sensitive rice cultivars. Plant Prod Sci 12: 185-192.
21. Lee JH, Park DS, Kwak DY, Yeo US, Song YC, et al. (2008) Yield and grain quality of early maturing rice cultivars as affected by early transplanting in Yeongnam plain area. Korean J Crop Sci 53: 326-332.
22. Li J, Zhang W, Wu H, Gou T, Liu X, et al. (2011) Fine mapping of stable QTLs related to eating quality in rice (Oryza sativa L.) by CSSLs harboring small target chromosome segments.

Breeding Sci 61: 338-346.

23. Nagata K, Takita T, Yoshinaga S, Terashima K, Fukuda A (2004) Effect of air temperature during the early grain filling stage on grain fissuring in rice. Japan J Crop Sci 73: 336-342.
24. Nishimura M, Yamauchi F, Ohuchi K, Hamamura K (1985) Evaluation of the eating quality of recent rice varieties and lines in Hokkaido-The relation between organoleptic and physicochemical qualities of milled rice harvested in an extremely col year and a very hot year during the summer. Res Bull Hokkaido Natl Agric Exp Stn 144: 77-89.
25. Sakai M, Okamoto M, Tamura K, Kaji R, Mizobuchi R, et al. (2010) 'Nikomaru', A high-yielding rice variety with superior eating quality and grain appearance under high temperature during ripening. Bull NARO Kyushu Okinawa Agri Res Centre 54: 43-61.
26. Takeuchi Y, Nonoue Y, Ebitani T, Suzuki K, Aoki N, et al. (2007) QTL detection for eating quality including glossiness, stickiness, taste and hardness of cooked rice. Breeding Sci 57: 231-242.
27. Takeuchi Y, Hori K, Suzuki K, Nonoue Y, Takemoto-Kuno Y, et al. (2008) Major QTLs for eating quality of an elite Japanese rice cultivar, Koshikari, on the short arm of chromosome 3. Breeding Sci 58: 437-445.
28. Tanoi M, Tomita K, Kobayashi A, Hayashi T (2010) Heat tolerance and grain quality of a new rice cultivar 'Akisakari'. Hokuriku Crop Su 45: 3-6.
29. Wada T, Tsubone M, Inoue T, Ogata T, Hamachi Y, et al. (2010) 'Genkitsukushi', a new cultivar with tolerance to high temperature during maturing period and high eating quality. Bull Fukuoka Agri Res Centre 29: 1-9.
30. Yanase H, Ohtsubo K, Hashimoto K, Sato H, Teranishi T (1984) Correlation between protein contents of brown rice and textural parameters of cooked rice and cooking quality of rice. Report of National Food Res Inst 45: 118-122.
31. Yun SH, Lee JT (2001) Climate change impacts on optimum ripening periods of rice plant and its counter measure in rice cultivation. Korean Journal of Agricultural and Forest Meteorology 3: 55-70.