Grain quality of rainfed rice (*Oryza sativa*) genotypes in Central Queensland, Australia

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Abstract
Water is a major cost (20-30%) for Australian rice production as the industry water use is very high (12.3 ML/ha) due to flood irrigation. Developing appropriate rainfed rice varieties provide alternatives for the rice industry to maintain growth while the cost for water is increasing and availability is decreasing. However, maintaining high grain quality from rainfed production systems may pose challenges. Thirteen dryland rice genotypes (7 long 6 medium grain lines) were tested during the summer rainy season in Alton Downs, QLD under rainfed and strategic irrigation management in the 2013/14 season. Measured grain quality parameters only differ due to varieties but not due to water management practice (rainfed vs strategic irrigation). Four of the medium grain varieties (Lasix XB, Inaminka XD, Linklaer A1 and Laski VII) produced grain yield of 4 – 5 t/ha with strategic irrigation but were compromised with low amylose and grain protein. The gel temperature was generally higher for long grain and lower for medium grain type varieties. The millout percentage however was not linked to grain type nor to irrigation method, and all tested varieties recorded millout in excess of 50%. All tested medium grain types were earlier for maturity compared to long grain type. Therefore, the planting time for the long grain type may need to be adjusted to maintain their yield and quality. Yield and detailed grain quality analysis from crop grown in wider agro-ecological zones with full growing seasons will be presented from crops planted in the 2014/2015 season.

Key words
Rainfed rice, Dry land rice, Water use efficiency, Rice quality

Introduction
Rice (Oryza sativa) is a major food crop for nearly half of the world's seven billion population. 90% of rice produced in the world is consumed in Asia. However, consumption of rice is also increasing since 1960s in Africa, Europe, USA and Oceania. In Australia rice is grown in three states (New South Wales, Victoria and Queensland) producing one million tonnes and is exported to 60 countries generating AU $ 800 million revenue per annum (RIRDC 2011).

Australia's climate in southern states (NSW, VIC) makes it ideal for production of high quality medium grain rice, grown predominantly as flood irrigated crop, consuming 11% of irrigated water use by rice industry. Water use by the rice industry gradually fell between 2000/01 and 2008/09 (2,223 GL in 2000/01, 631 GL in 2004/05 and 101 GL in 2008/09) mainly due to smaller planted areas during the drought years and increasing cost for irrigation water.

Frequent drought episodes limit water availability, severely impacting rice production. For irrigated rice in Australia, cost of water (20-30% of the total variable costs) can be often greater than any other inputs, therefore, reducing water use, can improve profit margins for industry. Improving WUE can be achieved by adoption of rainfed production system in the wet tropics, adoption of strategic irrigation methods and maximization of rainfall interception for irrigation, by developing suitable cropping system, efficient irrigation management practice, and use of water use efficient germplasm. Producing more rice with less water is current and future challenge for all rice producers globally.

Rainfed rice improve WUE in region receiving appreciable summer rainfall (>500 mm during the growing season). French and Schultz (1984) model suggests the upper limit of WUE in modern grain varieties to be 22 kg/ha/mm. This model when applied for the rainfed rice (600 mm rain) can predict as much as 13.2 t/ha of dry biomass, with the harvest index of 0.6, could produce 8 t/ha of paddy. Theoretically rainfed rice industry can be developed in the wet tropics provided water loss due to run-off, deep drainage and evaporation can be controlled.

Dryland rice production in broad-acre can often confounded with abiotic stresses causing low yield. Realization of water savings combined with high yields, and attainment of good grain quality depends on crop judicious crop management under rainfed production system. Rainfed rice industry for broad-acre production has been adopted in number of countries such as Brazil, India, the Philippines, China, etc.

Grain quality is bottom line for rice industry. Water management for rice impact on grain quality. Rice grain quality is determined by measurable physical, chemical, and sensory characteristics that are genetic or acquired. Physical grain qualities include shape, translucency and whiteness of the grain; and cooking qualities include texture when hot and cold, cooking time and digestibility, while the sensory quality parameters include fragrance, aroma and taste. Grain quality is defined by the markets based on the intended end use of the rice.

Rice varieties, climatic conditions such as water availability and temperature, crop management, timing and uniform maturity of the crop, affects yield and quality(Chen, Wang et al. 2012). While grain quality traits are largely genetically inherited, environmental conditions, agronomic practices, grain handling and storage affect grain quality. Apart from effect of management on grain yield and physical and chemical grain quality parameters, cooking and sensory quality parameters are also significantly influenced by crop water management. Guo, Mu et al. (2007) noted that grain quality parameters such as amylose content, gel consistency, gelatinization temperature and protein content of rice registered significantly higher for aerobic than for flooded rice. However, cooking quality parameters (length, breadth of kernel, L/B ratio, elongation ratio, water uptake, volume expansion ratio, cooking time and keeping quality parameters), were not significantly reduced when grown in rainfed system in China.

Variety IAC 201 and Carajás were evaluated under rainfed and sprinkler-irrigated conditions in Brazil (Crusciol, Arf et al. 2008). The milling yield of polished grains for the Caritas was 5.1% higher than that of cultivar IAC 201. Lower water availability induced increases in protein, N, P, Ca, Mg, Fe, and Zn contents but reductions in S and Cu in the polished grains irrespective of varieties. Crusciol, Arf et al. (2008), highlighted the enhancement of nutrients in rainfed crop and increase in milling recovery and yield by supplementary sprinkler irrigation. Given that rice varieties have different physical, chemical, and sensory characteristics contributing to eating quality, it is important to consider each variety's detailed grain characteristics before making a decision for commercial scale of planting. This paper present the quality parameter of 13 lines of rice grown with and without supplementary irrigation during wet season of 2013/2014 season in central Queensland Australia.

Materials and methods

Rice cultivars

Seed samples of thirteen rice genotypes were obtained from Australian Agricultural Technology Ltd (AAT). The genotypes used in the experiment are Lasik VII, Sunkiss PII, Linklatter A1, Linklatter BII, Dummeriney II, Lasik IX, Inaminka MB, Lasix XB, Lasik X11, Inaminka XB, Inaminka XD, Unnamed, Duminey. Two new varieties of rice samples (polished rice) were received from China as standard check variety for grain quality analysis only as benchmark lines for grain quality for Chinese market, but these were grown as flood irrigated rice in China, milled and marketed in China. There were seven long grain type and six medium grain type varieties in the trial (Table 2)

Experimental design and cultivation conditions

Performance genotype were tested under rainfed and strategic irrigation conditions. Strategic irrigation is supplementary water application to rice crop when soil moisture at 20-30 cm depth is below refill value (21 mm/100 mm). Same volume of water applied to all varieties in the strategic irritation. Strategic irrigation is applied by using drip irrigation. Water use efficiency is calculated as Mega liter water (from irrigation and rainfall)/ton of rice.

Experiment was conducted during wet season (January-May 2014) and it has experienced typically an average year from rainfall point of view.

A randomized complete block design (RCBD) with two replications for each cultivar was used in the field experiment, at Alton downs, Rockhampton, central QLD Australia.

The rice seeds were directly seeded by tractor mounted seed dibbler directly into the soil during the wet season (January-May 2014). The field was fertilized with 100kg N/ha before planting of the crop entirely as basal application.

The crop was planted in row configuration of 50 cm x 5 cm between and within row. The direct seeding of the seeds maintained of 40kg /ha of seed rate. There were 15 rows, in 45.5 long plots (170.63m2 per plot), that allowed for the harvest by the plot harvester.

Sampling for yield determination
Yield assessment were carried out at two levels. Whole plot harvest as performed by plot harvester. Machine harvest tend to leave some seeds in the plants and also caused some shattering of seeds particularly on the long grain types lines. Therefore, for accurate yield assessment, 2 m2 sample plot areas were marked in each plot, and harvested, and threshed manually by hand to present the yield data. Three random two meter square areas were marked for the sampling for harvest and yield estimated. Grains from plant sampled in the sample plot were manually threshed and dried to 12 percent moisture. Weight of dry seeds from sample plot areas recorded and yield were calculated as grain weight t/ha.

Grain quality analysis
Random paddy samples of 150 g was collected from each of these harvested varieties was used for grain quality assessment purpose. The paddy samples were dried to 12 percent moisture for send to DPI NSW, Rice Chemistry Laboratory at Yanco Agriculture Institute, Industry and Investment NSW (I&I NSW). The grain quality analysis was undertaken to support rice breeding/variety evaluation program and quality evaluation program to ensure that varieties to be release are of superior agronomic and grain quality, and therefore commercially viable.

Assessment of rice grain quality parameters were determined following the rice grain quality assessment protocol DPI NSW (Ward and Martin 2009).

Physical qualities
Physical properties of the grain are those which are recognisable in the marketplace. This involved assessment of rice lines for the percentage of grains remaining whole after milling (or millout), grain dimension, chalk and colour.

Millout
Millout is a key determinant of grain quality, as a high millout equates to a high economic return. Instruments used for milling process includes dehusking machine, polishing machine, and grain grader to separate broken from the whole grain. Harvested grain were aspirated to remove debris and the paddy grain is collected. A sample of 150 g of paddy grain is then dehulled to produce brown grain. The brown grain is milled, whereby the bran layer is removed to produce white grain. Whole milled, white grain is then separated from the broken grains. The weight of the whole grain was used to calculate the millout percentage.

Grain dimension and chalk content
Grain dimension and chalk content were determined with an instrument that uses a camera to capture the image of single grains. Image analysis and Artificial Neural Network are then used to determine these physical qualities of the grain. The length and width ratio is used to describe grain shape, e.g. medium or long grain. Chalk is defined as the opaque specks in a rice grain desirable only in Arborio and Sake rices.

Colour
A white translucent grain is desired in all markets. A scan of a milled sample by the hand-held spectrophotometer provided information about the lightness/darkness as well as the colour (whiteness/ yellowness).

Cooking qualities

Amylose content

Wet chemistry method followed for amylose determination as amylose binds with iodine to produce a blue colour. The intensity of the blue colour was measured with a spectrophotometer to determine the amylose content.

Gelatinisation temperature

Gelatinisation temperature is the temperature at which rice starch begins to melt (gelatinise) and take up water. It is measured with a Differential Scanning Calorimeter, an instrument that measures energy transfer to and from a sample while it is heated.

Viscosity

Viscosity is a measure of the energy required to stir a sample of rice flour and water as it is heated and cooled. Each variety has a different viscosity profile depending on how the temperature causes the starch to gelatinise, proteins to denature, lipids to alter and water to interact with the flour. Different inflection points of the resultant viscosity curve provide information about the cooking properties of the grain. It was measured with a viscometer.

Nitrogen content

The nitrogen content of milled grain was predicted by NIR (near infrared). Protein content in milled rice is generally around 7%, but can reach up to 12% if the soil has a high nitrogen load.

Statistical analysis

The data obtained for the disease screening was analysed using Analysis of Variance (ANOVA). The analysis was performed using GenStat statistical package, Version 16. (VSNI Ltd, UK). A value of $p \leq 0.05$ was considered as significant. Variation within the entry has also been estimated and presented and standard deviation of measured parameter for each genotypes.

Results and discussion

Grain yield

All long grain types were longer duration (160-180 days) for maturity whereas all medium grain types matured earlier (150-160 days). In the field trials, grain yield of the medium grain types varied from 2.19 to 3.85 t/ha for rainfed cultivation and 3.48 to 4.68 t/ha for strategic irrigation (Table 1). Three highest yielding varieties under strategic irrigation were Lasix XB (4.68), Inaminka XD (4.57 t/ha), and Linklatter A1 (4.48 t/ha), whereas under rainfed condition Sunkiss P11 produced the highest yield (3.85 t/ha). Yield from the field trials for this season was under non-optimised growth conditions (with respect to fertilizer, spacing, planting time and water). On an average, strategic irrigation increased rice yield compared to rainfed system by 224%. The interaction effects due to variety and irrigation method was not significant.

Table 1: Yield and millout of rice varieties in two different irrigation management system for rainfed rice genotypes (M- medium grain and L- long grain).

Varieties	Lines	Grain type	Paddy yield (t/ha)		Millout (mean ± SD)	
			Rainfed	Strategic irrigation	Rainfed	Strategic irrigation
Lasik VII	3	M	2.12	4.20	0.51±0.03	0.43±0.01
Sunkiss PII	4	M	3.85	3.48	0.59±0.08	0.56±0.03
Linklatter A1	6	M	2.71	4.48	0.52±0.02	0.40±0.01
Linklatter B1	9	L	0.10	3.03	0.55±0.01	0.48±0.08
Dummeriney II	10	L	0.84	2.38	0.59±0.00	0.58±0.00
Lasik IX	11	L	0.49	3.08	0.59±0.02	0.60±0.00
Inaminka MB	12	L	0.26	2.81	0.63±0.01	0.59±0.01
Lasix XB	13	M	2.19	4.68	0.60±0.00	0.60±0.05
Lasik XII	15	L	0.11	1.34	0.58±0.03	0.58±0.01
Inamika XB	16	L	0.12	2.24	0.56±0.05	0.61±0.00
Inaminka XD	17	M	2.99	4.57	0.59±0.00	0.56±0.03
Unnamed	18	L	0.10	1.81	0.59±0.01	0.59±0.00
Duminey	19	M	2.71	3.64	0.58±0	0.57±0.02
Average			1.43	3.21	0.57	0.55
LSD (0.05%)	Treatment (T)		0.358***		0.174 ns	
	Variety (V)		0.912***		0.037 ***	
	T×V		1.289 ns		0.064 ns	
CV(%)	Treatment		2.5		2.4	
	Varieties		27		3.1	

Millout

Millout is a key determinant for variety, as a high millout equates to a high economic return. The mill out varied significantly between the varieties. The millout ranged from 51-63 percent in rainfed and 40-61 percent in strategic irrigation (Table 1). Highest yielding varieties Lasix XB, and naminka XD recorded higher millout as well, whereas Linklatter A1 had lowest millout of 40% only. Hence this variety cannot be recommended for general production purpose. Chalk is an unfavourable traits for cooking rice. It is caused by poorly packed crystalline regions of starch that reflect rather than transmit light. The susceptibility to form high amounts of chalk is a genetic trait, but strongly influenced by high temperature during grain filling.

Amylose content

Cooking qualities of the rice are generally associated with the grain variety. Amylose content varied significantly due to variety only and not due to water management. Amylose content of tested lines varied from as low as 17 to as high as 24.4. Highest amylose content recorded by Lasik XII and unnamed variety whereas lowest amylose content was observed in variety Linklater B1 (Table 2).

Table 2: Amylose and gel temperature of rice varieties in two different irrigation management system

Varieties	Lines	Grain type	Amylose % (Yanco) (mean ± SD)		Gel.Temp (mean ± SD)	
			Rainfed	Strategic irrigation	Rainfed	Strategic irrigation
Lasik VII	3	M	18.87±0.25	19.16±0.64	64.91±0.23	65.29±0.48
Sunkiss PII	4	M	21.45±3.78	19.2±0.16	68.82±5.1	65.19±0.59
Linklatter A1	6	M	19.11±0.42	19.75±0.11	64.82±0.1	64.85±0.61
Linklatter B1	9	L	17.15±0.05	17.69±0.63	75.05±0.24	75.1±0.29
Dummeriney II	10	L	18.16±0.22	19.15±0.01	74.55±0.01	74.78±0.12
Lasik IX	11	L	18.16±0.01	18.82±0.33	74.46±0.13	74.72±0.20
Inaminka MB	12	L	18.45±0.02	18.53±0.14	74.48±0.30	74.71±0.04
Lasix XB	13	M	19.6±0.57	20.09±0.34	64.92±0.23	65.37±0.09
Lasik XII	15	L	24.07±0.36	24.37±0.17	71.96±0.07	71.97±0.11
Inamika XB	16	L	21.41±4.09	24.43±0.2	68.54±5.15	72.05±0.04
Inaminka XD	17	M	19.33±0.63	19.26±0.2	64.74±0.91	65.11±0.47
Unnamed	18	L	24.16±0.13	24.01±0.07	72.04±0.01	72.06±0.04
Duminey	19	M	19.39±0.45	19.32±0.53	65.18±0.11	64.94±0.7
Average			19.95	20.29	69.57	69.7
LSD (0.05%)	Treatment (T)		1.59		1.769 ns	
	Variety (V)		1.868***		2.186 ***	
	T×V		2.352		2.98 ns	
CV(%)	Treatment		0.6		0.2	
	Varieties		4.3		1.4	

Milled, white rice is composed of ~93% starch (amylose and amylopectin), ~7% protein and ~0.5% lipids. The composition, structure and interaction of these components largely define the cooking qualities of rice. Most cooking quality assessments are made at the advanced line stage for amylose. Amylose content can range from 15–30% and can indicate the cooked texture of the rice. Low amylose content produces a soft cooking rice where high amylose usually produces a firm and fluffy rice.

Gelatinisation temperature

Gelatinisation temperature differ significantly only with variety and not by irrigation method or interaction between variety x and irrigation method. Rice has a gelatinisation temperature of 65–80°C. Gel temperature of these tested lines varies from 64-75. The higher gel temperature has been recorded by all long grain types compared to mid grain types (Table 2).

Nitrogen and protein content

Grain physical qualities can be affected by the growth conditions of the plant, in particular high temperatures during grain filling, field fertilisation (e.g. N kg per hectare) and harvest moisture. The grain N, and protein content differed only due to varieties and not by irrigation, and the interactions of N x V (Table 3). Grain N content ranged from 1.3-1.8%. Generally N content is greater in long-grain compared to medium and also negatively correlated with the yield.

Table 3 Nitrogen and protein of rice varieties in two different irrigation management system

Varieties	Lines	Grain type	N% (mean ± SD)		% protein (mean ± SD)	
			Strategic Irrigation	Rainfed	Strategic Irrigation	Rainfed
Lasik VII	3	M	1.66±0.03	1.56±0.08	9.89±0.16	9.3±0.45
Sunkiss PII	4	M	1.61±0.04	1.56±0.04	9.6±0.24	9.31±0.27
Linklatter A1	6	M	1.59±0.09	1.49±0.03	9.45±0.53	8.87±0.19
Linklatter B1	9	L	1.79±0.17	1.82±0.05	10.68±1.02	10.8±0.3
Dummeriney II	10	L	1.84±0.14	1.75±0.1	10.97±0.83	10.4±0.57
Lasik IX	11	L	1.83±0.02	1.81±0.05	10.89±0.12	10.76±0.32
Inaminka MB	12	L	1.79±0.02	1.84±0.02	10.67±0.11	10.97±0.11
Lasix XB	13	M	1.36±0.3	1.4±0.21	8.08±1.8	8.31±1.25
Lasik XII	15	L	1.67±0.03	1.61±0.04	9.94±0.16	9.59±0.21
Inamika XB	16	L	1.65±0.09	1.68±0.01	9.8±0.55	10.01±0.06
Inaminka XD	17	M	1.54±0.01	1.58±0.06	9.15±0.08	9.43±0.35
Unnamed	18	L	1.71±0.07	1.67±0.02	10.2±0.41	9.96±0.15
Duminey	19	M	1.51±0.04	1.57±0.06	8.98±0.25	9.35±0.37
Average			1.66	1.64	9.87	9.77
LSD (0.05%)	Treatment (T)		0.345 ns		2.051 ns	
	Variety (V)		0.16 ***		0.955 ***	
	T×V		0.188 ns		1.121 ns	
CV (%)	Treatment		1.6		1.6	
	Varieties		4.5		4.5	

Conclusion

Large genetic variation noted among rainfed rice genotypes for yield and quality parameters. This is leading towards the opportunity for multiplication trials particularly in wet tropics in NQLD. Recent trials have been focused on optimizing the agronomic practices for the elite lines and rigorous assessment of grain quality.

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