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Rice grain discoloration effect on physical properties and head rice yield in three rice cultivars

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RESEARCH ARTICLE

Abstract

Rice grain discoloration is a complex disease which develops by a range of micro-organisms. Effects of fungal agents such as *Alternaria* sp., *Curvularia* sp., *Cladosporium* spp., *Bipolaris* spp. on the physical properties and head rice yield (HRY) were examined during the cropping season 2013-2014. The experiment was conducted in factorial design with two factors; three rice cultivars of Hashemi, Gohar and Khazar, and two grain disease severity levels (high and low) based on a randomised complete design with four replications. In order to attain high disease severity level, water was sprayed at the heading stage of the crop. The grains axial dimensions, geometric and arithmetic mean diameters, sphericity, surface area, volume, slenderness ratio, 1000-grain weight, as well as HRY were measured at a moisture content of 9% (wet basis). The average of length, width, thickness, surface area, volume and 1000-grain weight at the high disease severity were found to be 7.64, 2.04, 1.67 mm, 20.375 mm^2, 13.796 mm^3 and 24.6 g, respectively, and at the low disease severity 7.78, 2.04, 1.69 mm, 20.944 mm^2, 14.341 mm^3 and 26.32 g, respectively. There were significant differences between the tested cultivars for all physical properties and HRY. The average HRY with high disease severity was 54.18% and 58.18% with low disease severity.

Keywords: head rice, milling, physical properties, rice disease

1. Introduction

Rice (*Oryza sativa* L.) is a staple food and one of the most important cereal crops, especially for Asia, but recently consumption outside Asia has increased (Orthoefer, 2005). Rice provides the bulk of daily calories for many animals and humans (Ryan, 2011). The result of a deficiency in food production has increased the price of food and the proportion of malnourished people in the world, which might result in economic and social unrest (Roy *et al.*, 2011).

Global warming and rice yield losses due to diseases and pests will reduce rice crop productivity (Phat *et al.*, 2005; Sheehy *et al.*, 2005). These yield loss may be as a result of seed borne pathogens that according to Khanzada *et al.* (2002) may cause seed rot, reduction of germination capacity, seed abortion and seed necrosis as well as seedling damage. Fungi growing on seeds can cause several damage such as necrosis, discoloration, seed abortion, shrunken seeds, and reduce seed yield (Pinciroli *et al.*, 2013).

Rice grain discoloration is a disease of great importance worldwide and it causes substantial damage in sub-tropical and tropical countries (Pizzatti and Cortesi, 2008). Farmers do not know when diseased grains are sown; rice yield of coming season will decrease due to the subsequent influences of diseases. It may lead to decreasing 1000-grain weight, numbers of filled grains per panicle and an increasing unfilled grain percentage (Phat *et al.*, 2005). Over 59 fungal genera and 99 species are associated with rice seeds (Neninger *et al.*, 2003). These fungi can be grouped into two categories: 'storage fungi' which usually are saprophytes and develop after harvest and 'field fungi' which are more or less parasitic and infect the grains before harvest.

The value of rice depends on its physical qualities after the harvesting (Ghadge and Prasad, 2012). One of the most important parameters for the rice processing industry is the percentage of whole grain) (Marchezan, 1991). Broken grain has half the market value of head rice (IRRI, 2004). The processing operations when improperly designed may generate rice kernel cracking and breakage and consequently a low marketing price.

The knowledge of the physical properties of the agricultural products is of fundamental importance during the harvesting, transporting and correct storage of grains (Bashar *et al.*, 2014; Ghadge and Prasad, 2012). The principal dimensions of rough rice are used for calculating power requirement during this process. Also physical properties of rough rice could affect its milling quality parameters like head rice yield (HRY) and degree of milling.

Researchers have determined the physical properties of rice on the effect of rice blast and sheath blight of selected cultivars (Candole *et al.*, 2000). The effects of seed borne fungi on grain quality of common rice cultivars in the Mekong Delta were investigated by Van Du *et al.* (2001). The results of their study showed that grain discoloration disease had significant effects on grain quality, rice milling recovery, cooking and eating quality, seed germination, seedling height and 1000-grain weight and sheath blight disease generally reduced kernel bulk density, but did not significantly affect HRY. Some of the physical properties such as axial dimensions, bulk density, particle density, angle of repose and the coefficient of friction of paddy rice have been determined and reported for some specific varieties and moisture contents by various researchers (Alizadeh *et al.*, 2006; Arora, 1991; Farahmandfar *et al.*, 2009; Kachru *et al.*, 1994; Reddy and Chakraverty, 2004; Varnamkhsti *et al.*, 2007; Zareiforoush *et al.*, 2009). Also some researchers have conducted studies on the milling properties of rice as affected by processing and crop properties (Corrêa *et al.*, 2007; Minaei *et al.*, 2007; Shitanda *et al.*, 2001; Wiset *et al.*, 2001; Yan *et al.*, 2005). However, there is a lack of information on the effects of grain discoloration on the physical properties and milling head rice of high quality and improved rice cultivars. Hence the objectives of this study were to examine the effect of rice grain discoloration disease on the physical properties of three rice cultivars (Hashemi, Gohar and Khazar), such as grains axial dimensions (length, width and thickness), geometric mean diameter, sphericity, arithmetic mean diameter, surface area, volume and slenderness ratio and 1000-grain weight, as well as HRY after milling.

2. Materials and methods

The experiments were carried out in the Rice Research Institute of Iran (RRII), Rasht, Iran, during the cropping season of 2013-2014. Three common rice cultivars, namely Gohar, Hashemi and Khazar were used as raw materials; Hashemi is a long-grain and high quality cultivar, whereas Gohar and Khazar are long-grain and improved high-yielding cultivars.

Rice plants were grown under two disease severity levels; high disease severity level (HDSL) or not protected, which was achieved by spraying overhead water at the heading stage and low disease severity level (LDSL) or protected, which was established by using a fungicide for protecting the panicles from fungi and without water spray. The experiment was conducted using a factorial design with two factors, cultivar (Hashemi, Gohar and Khazar) and grain disease severity levels based on randomised complete design in four replications.

After land preparation, the seedlings were manually transplanted in plots of 4 m × 2.75 m. Hill to hill and row to row spacing were considered to be 20 cm × 20 cm. At the time of transplanting, 50 kg of nitrogen and potassium fertilisers were applied to the soil. The first weeding was started two weeks after transplanting and the second weeding was done two weeks after the first weeding using 50 kg nitrogen fertiliser in top dressing.

At the maturity stage, 300 panicles were selected from each plot, sealed in polyethylene bags and then transported to the laboratory for the next experiments. In order to reduce moisture content of the paddy sample to the desired level of 9% (wet basis), the samples were placed in an electric oven at a temperature of 40 °C until the desired moisture content was achieved (Yang *et al.*, 2003).

To determine the axial dimensions of grains, 50 paddy grains from each sample were randomly selected and picked up carefully, and then three principal dimensions of brown rice were recorded. Length (L), width (W), and thickness (T) as shown in Figure 1 were measured using a micrometer gauge (Mitutoyo, Kawasaki, Japan) reading to 0.01 mm.

The sphericity and geometric mean diameters can be expressed as follows (Mohsenin, 1986):

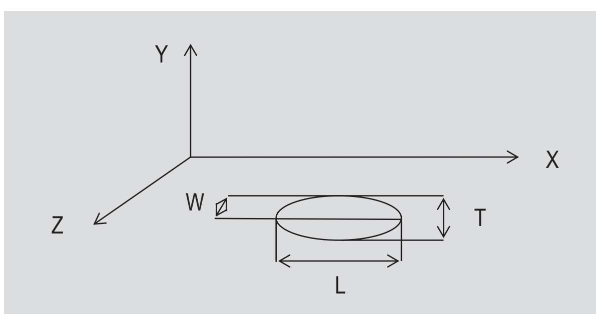

Figure 1. Coordinate axes and dimensions of rice grain (X = length (L), Y = width (W), Z = thickness (T)).

$$D_g = (LWT)^{1/3} \quad (1)$$

$$\phi = \frac{(LWT)^{1/3}}{L} \quad (2)$$

Where, φ is the sphericity (%), L, W and T are length, width and thickness of the grains (mm), respectively, and D_g is the geometric mean diameters (mm).

According to Jain and Bal (1997), surface area and slenderness ratio can be expressed as follows:

$$S = \frac{\pi B L^2}{2L - B} \quad (3)$$

$$B = (WT)^{0.5} \quad (4)$$

$$S_r = \frac{L}{W} \quad (5)$$

Where, S is the surface area (mm^2), B is a coefficient and S_r is the slenderness ratio of the grains.

According to Sharma *et al.* (1997) and Mohsenin (1986), volume and arithmetic mean diameter can be expressed as follows:

$$V = \frac{\pi B^2 L^2}{6(2L - B)} \quad (6)$$

$$D_a = \frac{L + W + T}{3} \quad (7)$$

Where, V is the volume (mm^3) and D_a is the arithmetic mean diameter (mm).

In order to measure the 1000-grain weight, one thousand paddy seeds of each sample were randomly selected and weighed with a digital balance.

In order to study the milling parameters of the test varieties, five samples of 140 g were randomly chosen from the dried paddy sample lots. A laboratory husker (Satake Engineering Co., Ltd., Tokyo, Japan) was used to de-husk the paddy samples. Then, the output of the husker which is brown rice, was fed to the whitener machine for bran removal. A laboratory friction-type rice whitener (McGill Miller, Brookshire, TX, USA) was used. A rotary indent separator (TRG 058; Satake Engineering Co., Ltd.) was used for separating head and broken kernels. A kernel being equal to or more than 75% intact was considered to be whole kernel (Farouk and Islam, 1995). The HRY was considered based on the total milled rice.

The effects of cultivar and grain disease severity level on the physical properties and HRY were investigated using analysis of variance (ANOVA), and mean significant differences were compared using a Tukey multiple range test at 5 and 1% significant level using SAS 9.1 software (SAS, Cary, NC, USA). The mean values, standard deviation, minimum and maximum dimensions of the grains were determined using Microsoft Excel 2007 (Microsoft, Redmond, WA, USA).

3. Results and discussion

The ANOVA of the effect of treatment, cultivar (A) and disease severity level (B) and their interactions (A×B) on the physical properties and HRY are given in Table 1. It can be seen that the effects of cultivar and disease severity on length, width (just cultivar effect), thickness, geometric and arithmetic mean diameter, sphericity (just cultivar effect), surface area and volume of the grains were significant (P<0.01). Also, the slenderness ratio of the grains was significantly affected by cultivar (P<0.05) and disease

Table 1. The analysis of variance of the measured grain (brown rice) physical properties at the moisture content of 9% (wet basis).[1]

Source of variations	df	Means square										
		Length (mm)	Width (mm)	Thickness (mm)	Geometric mean diameters (mm)	Arithmetic mean diameter (mm)	Sphericity	Surface area (mm^2)	Volume (mm^3)	Slenderness ratio	1000-grain weight (g)	Head rice yield (%)
Treatment	23	0.6752**	0.02059**	0.00528**	0.01466**	0.06964**	0.00099**	5.5666**	2.796**	0.3230*	25.25**	39.43**
Cultivar (A)	2	1.6241**	0.05111**	0.01137**	0.0333**	0.1645**	0.00243**	12.9427**	6.0740**	0.74433**	54.41**	50.62**
Disease[2] (B)	1	0.11934**	0.00003ns	0.00341**	0.00664**	0.0187**	0.000048ns	1.9425**	1.7769**	0.0072ns	16.83*	94.60**
A×B	2	0.0043ns	0.0003ns	0.00013ns	0.000017ns	0.00017ns	0.0000187ns	0.0033ns	0.02752ns	0.05972ns	0.29ns	0.67ns
Error	18	0.01093	0.00107	0.0003	0.00071	0.00146	0.00002	0.16275	0.16015	0.07979	2.73	8.21
CV (%)		1.354	1.605	1.037	0.9054	1.003	1.167	1.952	2.844	7.254	6.48	5.1

[1] *P<0.05; **P<0.01; ns = not significant; CV = coefficient of variation.

[2] Disease severity level

severity (P<0.01). The interaction effect of A×B on the physical properties and HRY was not significant (P>0.05).

The comparison of the means of the physical properties for the tested cultivars in the two disease severity levels is given in Table 2. The results revealed that the length and thickness of the grains with the LDSL were considerably higher than that of the HDSL which resulted in higher geometric and arithmetic diameters, as well as 1000-grain weight in LDSL. There were no significant differences between the width, sphericity and slenderness ratio in the two disease severity regimes. However, there were significant differences between the surface area and volume in the two disease severity regimes. The increase in the values for surface area and volume might be attributed to its dependence on the three principal dimensions of the rice grains. The slenderness ratio (ratio of grain length to width) which describes the shape of the grain also increased with increasing severity of disease, which can be the result of pathogens attack during the grains ripening stage. The size and shape are important in designing of separating, harvesting, sizing and grinding machines (Altuntas *et al.*, 2005).

It can be seen that grain discoloration significantly affected HRY (Figure 2). The results revealed that the HRY of the grains with LDSL (58.18%) was significantly higher than that for HDSL (54.21%). There were significant differences between the tested varieties in all of the physical properties and HRY. Liu *et al.* (2009) investigated thickness, aspect ratio, equivalent diameter, sphericity, surface area, volume, bulk density, true density, porosity, and thousand-seed

Table 2. The effects of cultivar and moisture on some physical properties of the grains.

Treatment[1]	Length (mm)	Width (mm)	Thickness (mm)	Geometric mean diameters (mm)	Arithmetic mean diameter (mm)	Sphericity	Surface area (mm^2)	Volume (mm^3)	Slenderness ratio	1000-grain weight	Head rice yield (%)
Khazar	7.4395^{b}	2.015^{b}	1.645^{b}	2.877^{b}	3.700^{c}	0.3873^{b}	19.454^{c}	13.083^{b}	3.802^{b}	22.52^{b}	56.32^{ab}
Gohar	8.239^{a}	1.983^{b}	1.709^{a}	2.999^{a}	3.977^{a}	0.3643^{c}	21.989^{a}	14.735^{a}	4.234^{a}	27.43^{a}	53.62^{b}
Hashemi	7.480^{b}	2.135^{a}	1.711^{a}	2.971^{a}	3.775^{b}	0.3986^{a}	20.535^{b}	14.388^{a}	3.645^{b}	26.50^{a}	58.65^{a}
HDSL	7.649^{b}	2.043^{a}	1.676^{b}	2.934^{b}	3.789^{b}	0.384^{a}	20.375^{b}	13.796^{b}	3.911^{a}	24.65^{b}	54.21^{b}
LDSL	7.790^{a}	2.045^{a}	1.700^{a}	2.967^{a}	3.845^{a}	0.382^{a}	20.944^{a}	14.341^{a}	3.876^{a}	26.32^{a}	58.18^{a}
Khazar× HDSL	7.37^{a}	2.0154^{a}	1.6299^{a}	2.86^{a}	3.67^{a}	0.3884^{a}	19.18^{a}	12.86^{a}	3.86^{a}	21.47^{a}	54.06^{a}
Khazar× LDSL	7.50^{a}	2.0155^{a}	1.6604^{a}	2.89^{a}	3.72^{a}	0.3862^{a}	19.72^{a}	13.30^{a}	3.73^{a}	23.57^{a}	58.57^{a}
Gohar× HDSL	8.18^{a}	1.9750^{a}	1.6960^{a}	2.98^{a}	3.95^{a}	0.3644^{a}	21.71^{a}	14.47^{a}	4.15^{a}	26.65^{a}	51.95^{a}
Gohar× LDSL	8.29^{a}	1.9920^{a}	1.7224^{a}	3.01^{a}	4.00^{a}	0.3642^{a}	22.26^{a}	14.99^{a}	4.31^{a}	28.22^{a}	55.30^{a}
Hashemi× HDSL	7.38^{a}	2.140^{a}	1.7043^{a}	2.96^{a}	3.74^{a}	0.4017^{a}	20.22^{a}	14.05^{a}	3.71^{a}	25.82^{a}	56.63^{a}
Hashemi LDSL	7.57^{a}	2.130^{a}	1.7189^{a}	2.99^{a}	3.80^{a}	0.3955^{a}	20.84^{a}	14.72^{a}	3.57^{a}	27.17^{a}	60.68^{a}

[1] HDSL = high disease severity level; LDSL = low disease severity level.

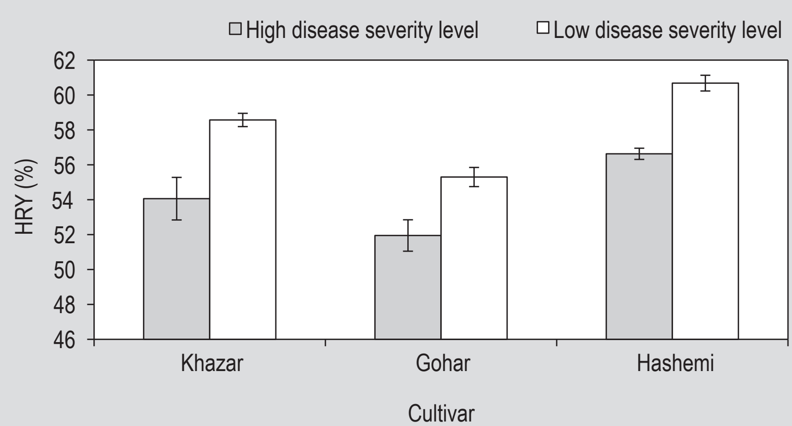

Figure 2. Effect of disease severity level and cultivar on the head rice yield (HRY) (P<0.05).

weight of rice varieties in the milling process. The results of their studies showed that the physical properties of rice kernels directly influenced the milling HRY. During rice milling, kernels are exposed to different compressive, bending, shear and frictional forces, and breakage can consequently occur (Shitanda *et al.*, 2002). As expected, our results demonstrated the negative effect of rice grain discoloration disease on the physical properties and HRY. This could be attributed to the seed physiological changes as influenced by pathogens attack. The result of the effect of rice grain discoloration disease can cause HRY loss and have a negative impact on physical properties such as 1000-grain weight, these results correspond with the findings obtained by Hai *et al.* (2007) and Phat *et al.* (2005).

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