

Changes in the Grain Quality of Rice with Respect to the Duration of Lodging Time

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Abstract The specific objective of this study was to determine the changes in grain quality of lodged rice with respect to the duration of lodging time and compare the changes with those of unlodged one. The rice 'Janganbyeo' was cultivated and half of paddy field was totally lodged at 30 days after heading. Both lodged paddy and unlodged paddy were harvested at intervals and used for the grain quality determination. The lodged rice did not show any remarkable changes in grain quality until the 4th day of lodging for rough rice and until the 2nd or the 4th day of lodging for brown rice and white rice. The overall grain quality of lodged rice could be kept for 2 to 4 days of lodging.

Keywords: lodging, rough rice, brown rice, white rice, grain quality

Introduction

Lodging is one of the most important constraints to the production of rice. Severe lodging prevents the transport of water, nutrients, and assimilates, resulting in poor grain filling of rice. Some lodged rice grains may also germinate on the panicle (viviparous germination), especially in cultivars with weak seed dormancy. Consequently, great losses in grain quality as well as grain quantity may occur due to the lodging of rice (1-7).

In the mean while, typhoon, a tropical cyclone with strong wind and heavy rain, has been one of the natural hazards, which can cause lodging of rice in Asia either tropical or temperate (1,8). Especially, the Korean peninsular which is one of the geographically passing zones of typhoon often experiences typhoon attacks and crop damages every year. Furthermore, more than half of the typhoons come in August or September when the rice paddy is on its ripening stage. In such case rice paddy is easily lodged and the lodged rice often results in higher yield loss and severer quality deterioration of rice (2).

A lot of research works have been reported on the lodging of rice with respect to occurrence of lodging due to wind and flooding (1,4,8-11), mechanism of lodging (2,3), methods to reduce the lodging damages (5,12-17), and characteristics of lodging tolerant varieties (6,7,14,18-21). A few literature reports have dealt with the effect of lodging on the rice quality (10,18,22,23). However, no reports have focused on the grain quality changes of rice with respect to the duration of lodging time. The specific objective of this study was to determine the changes in grain quality of lodged rice with respect to the duration of lodging time and to compare the changes with those of unlodged one.

In this study the rice 'Janganbyeo' was used. The first reason is that it is a medium maturing variety which often experiences lodging during the ripening stage by typhoon attacks in August or September (17). The second reason is that it is relatively tolerant to lodging and suitable for cultivating in the central filed of South Korea (17).

Materials and Methods

Materials Both lodged and unlodged samples in the form of paddy and brown rice were supplied by the National Crop Experiment Station (NCES), Hwaseong-si, Gyeonggi-do, South Korea. According to NCES, the rice 'Janganbyeo' was cultivated under basal fertilizer conditions, and about half of paddy field was totally lodged manually until the panicles touch the surface of field at 30 days after heading. Both lodged and unlodged paddies were harvested at interval of 0, 2, 4, 6, 8, 11, 13, 15, 20, and 23 days, and solar dried to the 15% moisture content. The dried paddy was dehulled to brown rice using a rice huller (Satake, THU35A; Stake Corp., Hiroshima, Japan), and then polished to white rice using a rice miller (Satake, MCM250; Stake Corp.).

Measurement of grain quality of rice Various grain quality properties of rice were determined according to the standard methods for Agricultural Experiments and Research (23). One-thousand grain weight (g), perfect paddy (%), and viviparous germination (%) were determined in case of rough rice. Yield of brown rice (%), 1,000 grain weight (g), and perfect brown rice (%) were determined in case of brown rice. Yield of milled rice (%), 1,000 grain weight (g), perfect kernel (%), and white belly (%) were determined in case of white rice.

Statistical analysis The analysis of statistical differences ($p < 0.05$) was performed using the statistical analysis program of SigmaPlot for Windows version 9.00 (Systat

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Software, Inc. Chicago, IL, USA).

Results and Discussion

Grain quality changes of rough rice during lodging The changes in 1,000 grain weight (g), perfect paddy (%), and viviparous germination (%) of lodged rough rice and unlodged rough rice ‘Janganbyeo’ are shown in Fig. 1 with respect to the duration of lodging time.

The changes in 1,000 grain weight (g) are shown in Fig. 1A. The lodged sample hold the initial value of 25.74 ± 0.05 g for 4 days, decreased to 25.24 ± 0.07 g on the 6th day of lodging, and then decreased again down to 23.92 ± 0.08 g. The average 1,000 grain weight of lodged sample was 24.93 ± 0.70 g during the entire lodging time. In the meanwhile, the average value 25.45 ± 0.38 g of unlodged sample was the same as the mean value of 25.45 g of rice ‘Ipumbyeo’ which was reported by Kim *et al.* (24). The 1,000 grain weight difference of 0.52 g between the unlodged and lodged sample seemed mainly due to the poor grain filling of lodged rough rice during the lodging time.

The changes in perfect paddy (%) of lodged and unlodged rough rice are shown in Fig. 1B. The lodged sample held the initial value of $98.09 \pm 0.34\%$ for 4 days, and then showed a sudden drop down to $83.74 \pm 2.43\%$ on the 8th day. The average after the 8th day was $85.88 \pm 1.58\%$. On the other hand, the unlodged sample showed the average of $98.48 \pm 0.43\%$ with the maximum of $99.31 \pm 0.09\%$ during the entire lodging time. Kim *et al.* (24) reported the similar results that the perfect paddy (%) of unlodged 5 varieties ranged from 97.03 to 98.60%. Oh *et al.* (10) also reported the value of unlodged rice ‘Hwajinbyeo’ as 98.7%, and that of 1-2 day lodged one as 96.8%, while Song *et al.* (22) reported the value of unlodged rice ‘Janganbyeo’ as 99.4%, and that of 70% lodged one as 98.7%. The perfect paddy (%) difference of lodged sample between the literature and our results seemed mainly due to different conditions and duration days of lodging.

The changes in viviparous germination (%) of lodged and unlodged rough rice are shown in Fig. 1C. The sign of viviparous germination of lodged sample was not observed until the 4th day of lodging, and afterwards the viviparity rapidly increased to $13.68 \pm 2.35\%$ on the 8th day. The average of lodged sample from the 8th day to the 23rd day was $12.97 \pm 1.50\%$. In contrast, unlodged sample did not show any signs of viviparity. Our results of viviparity seemed similar to or not so different from those reported by Ju *et al.* (25). They reported the viviparous germination (%) values of rice ‘Janganbyeo’ with different days after heading (25, 35, and 45 days) were 0.2, 2.4, and 6.2% after 4 days of lodging, 3.0, 15.8, and 12.9% after 8 days of lodging, and 11.9, 40.9, and 31.4% after 12 days of lodging, respectively. The discrepancy might be due to the differences in the cultivating conditions during the lodging experiment.

It can be summarized from the above results that the lodged rough rice did not show any remarkable changes in 1,000 grain weight (g), perfect paddy (%), and viviparous germination (%) for 4 days of lodging. In other words, the grain quality of lodged rough rice could be kept until the 4th day of lodging.

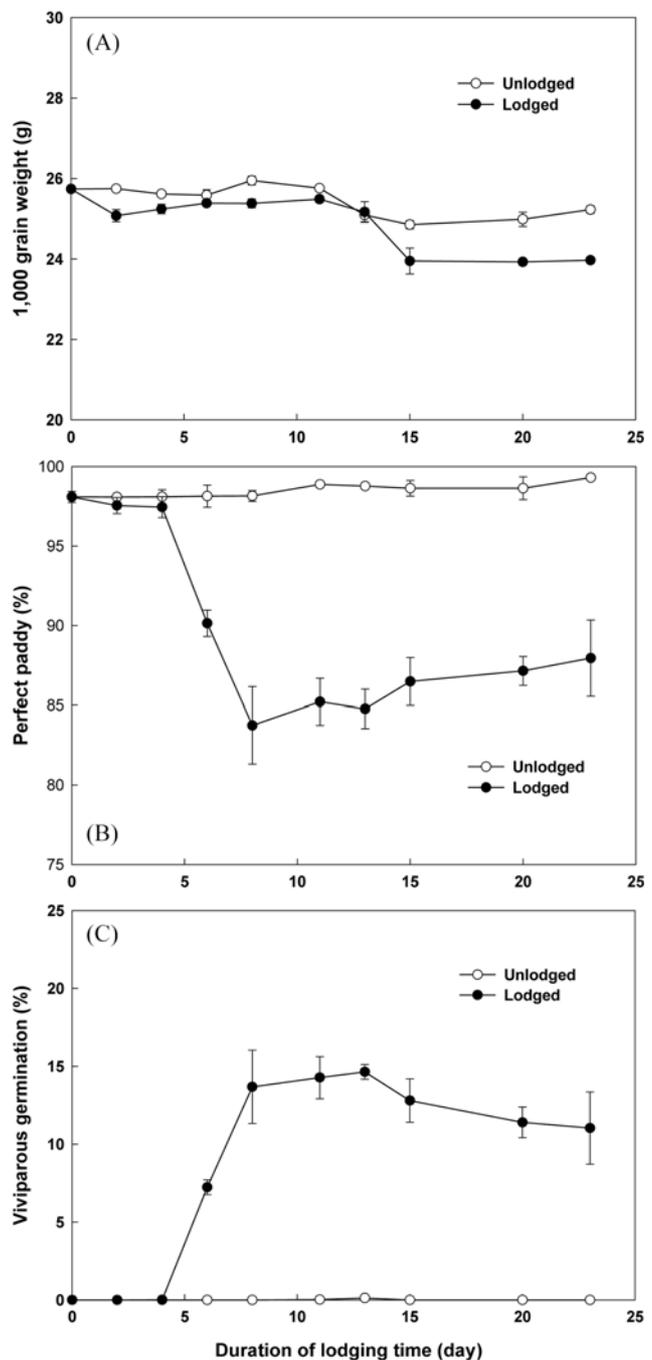


Fig. 1. Changes in 1,000 grain weight (A), perfect paddy (B), and viviparous germination (C) of lodged rough rice and unlodged rough rice of ‘Janganbyeo’ with respect to the duration of lodging time.

Grain quality changes of brown rice during lodging

The changes in yield of brown rice (%), 1,000 grain weight (g), and perfect brown rice (%) of lodged brown rice and unlodged brown rice ‘Janganbyeo’ are shown in Fig. 2 with respect to the duration of lodging time.

The changes in yield of brown rice (%) are shown in Fig. 2A. The lodged brown rice kept the initial value of $82.59 \pm 0.06\%$ for 2 days, showed a sudden drop down to $81.52 \pm 0.10\%$ on the 6th day, hold the similar value

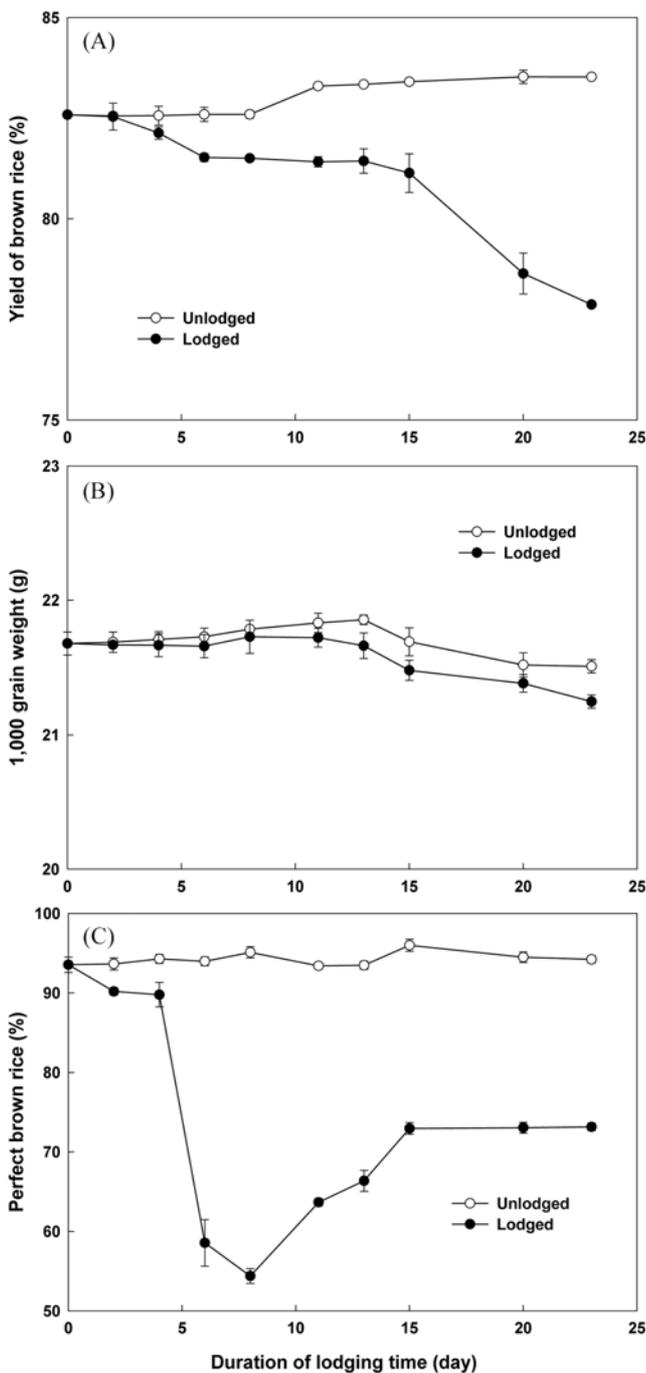


Fig. 2. Changes in yield of brown rice (A), 1,000 grain weight (B), and perfect brown rice (C) of lodged brown rice and unlogged brown rice of 'Janganbyeo' with respect to the duration of lodging time.

($81.40 \pm 0.16\%$) until the 15th day, and then decline again down to the minimum of $77.87 \pm 0.01\%$. On the other hand, the unlogged brown rice held the value of $82.58 \pm 0.02\%$ similar to the initial value until the 8th day, and then kept the increased level of $83.42 \pm 0.11\%$ during the later stage of lodging. Kim *et al.* (24) reported the similar results that the yield of brown rice (%) of unlogged 5 varieties was $83.25 \pm 0.87\%$ (81.75 - 83.94%). Cho *et al.* (18) also reported that the yield of brown rice (%) of unlogged rice

'Janganbyeo' was 82%. According to Oh *et al.* (10), the yield of brown rice (%) of unlogged rice 'Hwajinbyeo' was 81.7% and that of 1-2 day lodged one was 80.5%, while Song *et al.* (22) reported that the value of unlogged rice 'Janganbyeo' was 83.6% and that of 70% lodged one was 83.3%. Jeong *et al.* (23) also reported that the value of unlogged rice 'Saechucheongbyeo' was 82.3% and that of totally lodged one was 82.1%. All the previous data seemed to overlap with our results. The minute difference between the literature data and our results seemed mainly due to different conditions and duration days of lodging.

The 1,000 grain weight changes of lodged brown rice and unlogged brown rice are in Fig. 2B. Both lodged and unlogged samples kept the initial value of 21.68 ± 0.09 g until the 2nd day. After the 2nd day, however, the lodged sample slightly decreased to 21.24 ± 0.05 g with the average of 21.59 ± 0.16 g, while the unlogged one showed a relatively higher increase to 21.85 ± 0.04 g with the average of 21.70 ± 0.16 g. Cho *et al.* (18) reported that the yield of brown rice (%) of unlogged rice 'Janganbyeo' was 21.0 g, which seemed to be in the ranges of our data. The 1,000 grain weight difference of 0.11 g between unlogged and lodged brown rice seemed mainly due to the poor grain filling of lodged sample during period of lodging time.

The changes in perfect brown rice (%) are shown in Fig. 2C. The perfect brown rice (%) of lodged brown rice steadily decreased from 93.53 ± 0.93 to $89.77 \pm 1.53\%$ for 4 days, suddenly dropped on the 4th day, reached the minimum value of $54.38 \pm 0.93\%$, and then increased again up to $73.14 \pm 0.47\%$. On the other hand, however, the unlogged sample showed a continuous, but slight increase from 93.53 ± 0.96 to $95.98 \pm 0.76\%$ with the average of $94.20 \pm 0.82\%$ during the whole lodging time. Kim *et al.* (24) reported the similar results that the perfect brown rice (%) of unlogged 5 varieties was $95.37 \pm 2.57\%$ (90.32 - 98.85%). It can be summarized that the lodged brown rice did not show any remarkable changes in yield of brown rice (%) and 1,000 grain weight for 2 days of lodging; while, in perfect brown rice (%) for 4 days of lodging. In short, the grain quality of lodged brown rice could be kept for 2-4 days of lodging.

Grain quality changes of white rice during lodging The changes in yield of milled rice (%), 1,000 grain weight (g), perfect kernel (%), and white belly (%) of lodged white rice and unlogged white rice are shown in Fig. 3 with respect to the duration of lodging time.

The changes in yield of milled rice (%) of lodged and unlogged white rice are shown in Fig. 3A. The lodged sample kept the initial value of $90.94 \pm 0.05\%$ for 4 days, and then began to decline down to the minimum of $83.72 \pm 0.52\%$. The average was $86.97 \pm 3.04\%$ through the whole period of lodging. On the other hand, the yield of milled rice (%) of unlogged sample averaged $90.85 \pm 0.46\%$ (90.04 - 1.36%), which was seldom fluctuating during the whole period of lodging time. Kim *et al.* (24) reported the similar results that the yield of milled rice (%) of unlogged 5 varieties was $89.53 \pm 0.91\%$ (88.68 - 90.54%). According to Oh *et al.* (10), the yield of milled rice (%) of unlogged white rice 'Hwajinbyeo' was 89.7%, and that of 1-2 day lodged one was 86.9%, while Song *et al.* (22) reported that the yield of milled rice (%) of unlogged white rice

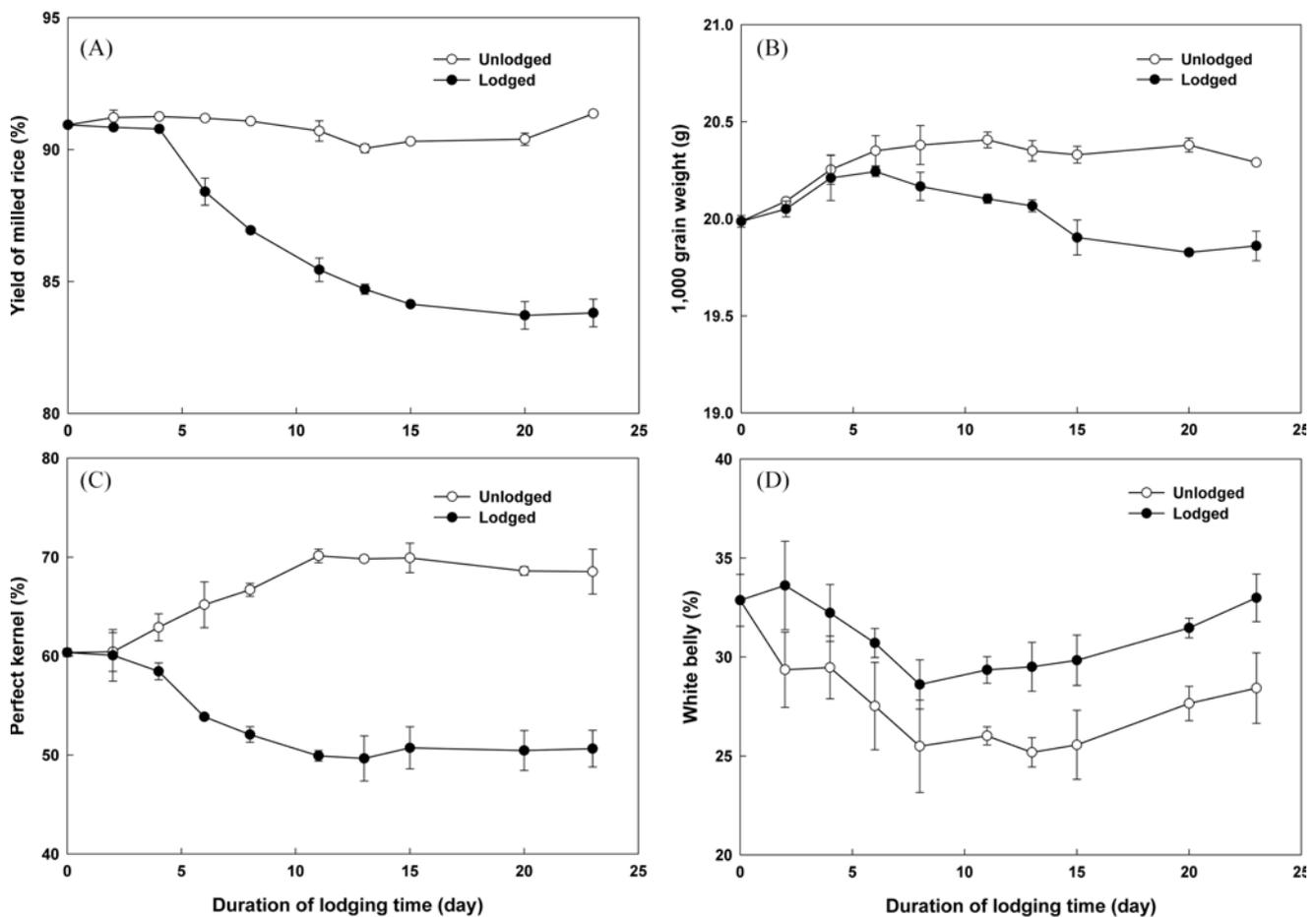


Fig. 3. Changes in yield of milled rice (A), 1,000 grain weight (B), perfect kernel (C), and white belly (D) of lodged white rice and unlogged white rice of 'Janganbyeo' with respect to the duration of lodging time.

'Janganbyeo' was 90.4% and that of 70% lodged one was 89.1%. Jeong *et al.* (23) also reported that the yield of milled rice (%) of unlogged white rice 'Saechucheongbyeo' was 91.8% and that of totally lodged one was 90.5%. All the above literature data seemed to overlap with our ones. The minute difference between the literature values and our results seemed mainly due to different conditions and duration of lodging days.

The changes in 1,000 grain weight of lodged and unlogged white rice are in Fig. 3B. Both lodged and unlogged samples increased until the 4th day. After the 4th day, however, the lodged brown rice began to decrease to 19.83 ± 0.02 g with the average of 20.04 ± 0.15 g, while the unlogged one kept the slight increased level with maximum of 20.41 ± 0.04 g and the average of 20.28 ± 0.14 g. Kim *et al.* (24) reported the similar results that the 1,000 grain weight of white rice of unlogged 5 varieties was 20.16 ± 1.24 g (18.41–21.64 g), which seemed in the ranges of our data. The 1,000 grain weight difference of 0.24 g between unlogged and lodged white rice seemed mainly due to the poor grain filling of lodged sample during the lodging period.

The changes in perfect kernel (%) of lodged and unlogged white rice are shown in Fig. 3C. Both lodged and unlogged samples kept the initial perfect kernel (%) of $60.35 \pm 0.41\%$ for 2 days. Afterwards the perfect kernel (%) of lodged

sample declined down to the minimum of $49.66 \pm 2.28\%$ with the average of $52.87 \pm 3.86\%$. On the other hand, the perfect kernel (%) of unlogged sample increased up to the maximum of $70.12 \pm 0.69\%$ and held the increased level with the average of $66.91 \pm 3.44\%$ during the later stage of lodging time.

The changes in white belly (%) of lodged and unlogged white rice are in Fig. 3D. The lodged white rice showed a sudden increase in white belly (%) from the initial value of $32.86 \pm 1.31\%$ to the maximum of $33.61 \pm 2.24\%$ on the 2nd day, decreased down to the minimum of $28.61 \pm 1.24\%$, and then increased again during the remaining period of lodging. The average was $31.11 \pm 1.76\%$ in the whole duration of lodging time. In the mean while, the white belly (%) of unlogged brown rice decreased, as the lodging began, down to the minimum value of $25.18 \pm 0.74\%$, and then increased again during the remaining period of lodging. The average was $27.75 \pm 2.40\%$ in the whole duration of lodging time.

It can be concluded that the lodged rough rice did not show any remarkable changes in grain quality until the 4th day of lodging with respect to 1,000 grain weight (g), perfect paddy (%), and viviparous germination (%). The lodged brown rice kept the grain quality for 2 days in case of 1,000 grain weight, and for 4 days in case of perfect brown rice. The lodged white rice also kept the grain quality for

2 days in terms of perfect kernel (%) and white belly (%) and 4 days in terms of yield of milled rice (%), and 1,000 grain weight. In conclusion, the overall grain quality of lodged rice could be kept for 2-4 days of lodging.

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