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Outbreak of Rice Panicle Blast in Jeonbuk Province of Korea in 2021

Hyunjung Chung[1], Woo-Il Lee[2,3]*, Soo Yeon Choi[1], Nak-Jung Choi[1], Sang-Min Kim[1], Ju-Yeon Yoon[3], and Bong Choon Lee[4]

[1]*Crop Foundation Research Division, National Institute of Crop Science, Rural Development Administration, Wanju 55365, Korea*

[2]*Disaster Management Division, Extension Service Bureau, Rural Development Administration, Jeonju 54875, Korea*

[3]*Department of Plant Protection and Quarantine, Graduate School of Plant Protection and Quarantine, Jeonbuk National University, Jeonju 54896, Korea*

[4]*Crop Protection Division, National Institute of Agricultural Sciences, Rural Development Administration, Wanju 55365, Korea*

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Rice panicle blast is one of the most serious diseases threatening stable rice production by causing severe damage to rice yields and quality. The disease is easy to occur under low air temperature and frequent heavy rainfall during the heading season of rice. In 2021, a rice panicle blast severely occurred in the Jeonbuk province of Korea. The incidence area of panicle blast accounted for 27.7% of the rice cultivation area of Jeonbuk province in 2021, which was 13.7-times higher than in 2019 and 2.6-times higher than in 2020. This study evaluated the incidence areas of rice panicle blast in each region of Jeonbuk province in 2021. The weather conditions during the heading season of rice, mainly cultivated rice cultivars, and the race diversity of the Jeonbuk isolates were also investigated. It will provide important information for the effective control of the rice panicle blast.

Keywords **:** panicle blast, race diversity, rice

*Corresponding author.
Phone) +82-63-238-1046, FAX) +82-63-238-1780
E-mail) hanyak12@korea.kr

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Rice is a major cereal crop and holds the highest proportion in the agricultural and forestry industry in Korea (Jeong et al., 2017, 2020). It was cultivated on approximately 0.7 million hectares, accounting for 47.4% of the total agricultural land in 2021, with a self-sufficiency rate of 92.1% in 2019. Rice blast disease caused by *Magnaporthe oryzae* contributes to severe yield losses of about 50% of rice productions by infecting leaves, stem, nodes, necks, and panicles of rice during the entire growing period (Dean et al., 2005; Katsantonis et al., 2017). The blast disease severely occurred due to the use of susceptible cultivars, large amounts of nitrogen fertilizer, favorable weather conditions, and the emergence of new races (Han, 1995; Han et al., 2001; Katsantonis et al., 2017; Luo et al., 1998; Ou, 1985). Since the 1960s, the Indica and Japonica hybrid rice cultivar, Tongil, and diverse Tongil-type varieties were developed to improve grain yield and disease resistance (Chung and Heu, 1991). Tongil-type varieties were grown in more than 75% of the total rice cultivation area in Korea in the 1970s. However, the proliferation of diverse genotypic rice cultivars triggered the genetic differentiation of rice blast fungus leading to the breakdown and loss of blast resistance in Tongil-type rice cultivars (Cho et al., 2007). Since the great breakdown of blast resistance of Tongil-type rice cultivars, lots of research on rice blast disease and breeding strategies of the disease-resistant rice cultivars have been conducted to prevent the outbreak of rice blast disease (Cho et al., 2007; Han, 1995; Han et al., 1994; Kim, 2018). Rice leaf blast had continuously declined since 2000 by the climate changes, advanced agronomical controls such as early rice planting and using less nitrogen fertilizer, and supply of chemical control agents. On the other hand, panicle blast increased nationwide due to frequent heavy rainfalls during the heading season in 2000, 2003, 2005, and 2008 (Lee et al., 2010). Moderate field infection of panicle blast causes more severe damage to rice yields under favorable conditions during the heading season. Therefore, the National Institute of Crop Science has annually monitored the incidence of rice blast disease. In 2021, a rice panicle blast explosively occurred in Jeonbuk province of Korea according to the monitoring of the nationwide panicle blast incidence. The incidence area was investigated by the disease incidence levels according to the manual of crop diseases and pests monitoring and control established by the Rural Development Administration (2016). Disease incidence level was divided into low (≤5%), medium (6-10%), high (11-20%), and severe (≥21%) according to the rate of diseased panicle, and the rate of diseased panicle was estimated by the following formula:

$$\text{The rate of diseased panicle} = \frac{\text{The number of diseased panicle}}{\text{Total number of the investigated panicle}} \times 100$$

The panicle blast incidence in Jeonbuk province increased gradually from 2019 to 2021, almost a 14-times increase within 3 years (Fig. 1, Supplementary Table 1). The incidence area of panicle blast in Jeonbuk province was 2,245.1 ha occupying 2.0% of the rice cultivation area in 2019, but in 2021, the incidence area was 30,707.1 ha occupying 27.7% of rice cultivation area. Among Jeonbuk regions, the disease incidence rate of Wanju, Gunsan, and Gimje was 0% in 2019, but highly increased to 64.14%, 54.81%, and 37.50% in 2021, respectively (Supplementary Table 2).

The favorable weather conditions for rice blast are known to be low air temperature and accumulated rainfall (Kang et al., 2019; Katsantonis et al., 2017; Kim et al., 2018; Lee and Park, 1979). Frequent rainfall during the heading season of rice is intimately related to panicle blast occurrence (Lee et al., 2010). Meteorological factors of Jeonbuk regions including Gimje and Wanju in August from 2019 to 2021 were compared to investigate the weather factors affecting the incidence of rice panicle blast. The average air temperature, total rainfall, and rainy days were obtained from daily weather observation data and daily climatological normals data provided by the Rural Development Administration (https://weather.rda.go.kr) and the Meteorological Administration (https://data.kma.go.kr). The average air temperature, total rainfall, and the number of rainy days in August 2019 and 2021 were compared in Wanju and Gimje, where the disease occurred most in Jeonbuk province in 2021. Those parameters in Wanju and Gimje were also compared with the mean values of climate parameters (climatological normals) from 2011 to 2020 (Table 1). The average air temperatures of Wanju and Gimje in August 2021 were 0.3°C and 0.8°C lower than in 2019, respectively, and 0.5°C and 1.1°C lower than the climatological normals, respectively. The accumulated rainfall of August in 2021 was 263.9 mm higher in Wanju and 269 mm higher in Gimje compared with 2019, and 94.1 mm higher in Wanju and 134.6 mm

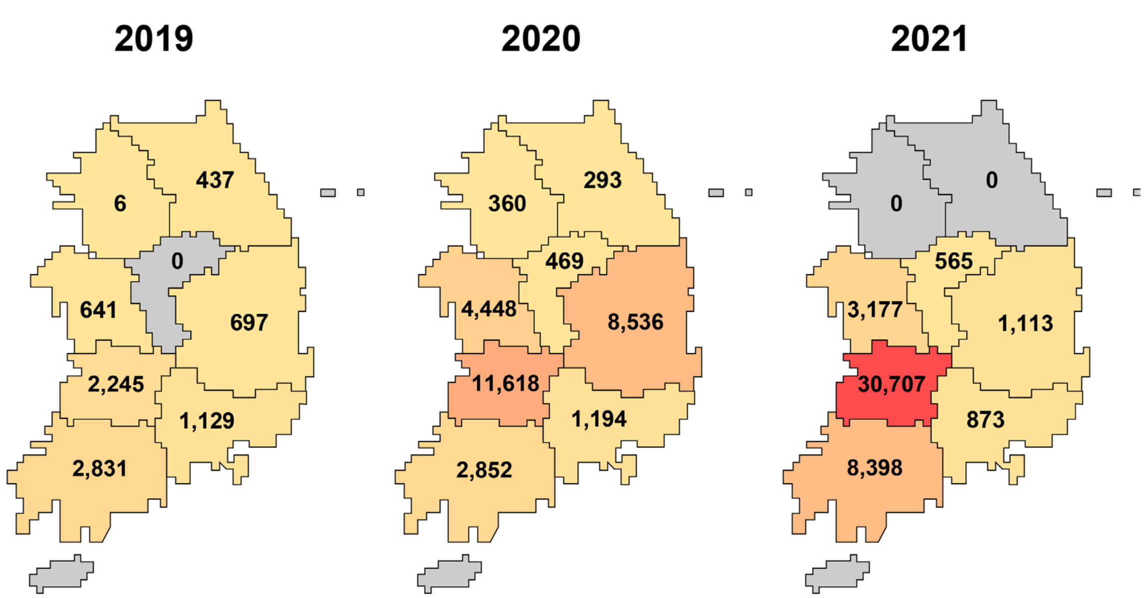

Fig. 1. Regional incidence of rice panicle blast in Korea from 2019 to 2021. The unit of incidence is hectares (ha).

Table 1. Meteorological characteristics in August of Wanju and Gimje in 2019 and 2021

Meteorological factor	Wanju			Gimje		
	2019	2021	Climatological normal[a]	2019	2021	Climatological normal
Average of air temperature (°C)	26.0 ± 2.7	25.7 ± 1.8	26.2 ± 1.4	26.1 ± 2.4	25.3 ± 1.6	26.4 ± 1.4
Total rainfall (mm)	110.8	374.7	280.6	137.0	406.0	271.4
Rainy days (day)	12	16	11	14	17	12

[a]Climatological normal indicates the average of climate parameters from 2011 to 2020.

higher in Gimje compared with climatological normals. The number of rainy days in Wanju and Gimje in 2021 was 3 to 5 days longer than 2019 and climatological normals. Most of the Jeonbuk regions also had lower air temperature and longer rainy days in 2021 and more rainfall in 2020 compared with 2019 (Supplementary Table 3). Correlation analysis was conducted to investigate the correlation between meteorological factors and disease incidence rates of Jeonbuk province in August 2019 and 2021 along with the climatological normals and average incidence from 2011 to 2020 (Supplementary Table 4). The correlation coefficients between the average air temperature and disease incidence in Iksan, Jinan, and Buan were –0.961, –0.968, and –1.000, indicating a significantly negative correlation. On the other hand, the correlation coefficients between the number of rainy days and disease incidence in Wanju, Jinan, Imsil, Sunchang, and Buan were 0.982, 0.997, 1.000, 1.000, and 0.954, indicating a significantly positive correlation. These results suggest that low air temperature and frequent rainfall during the heading season in Jeonbuk would be enough to develop the rice panicle blast.

The emergence of new rice blast races or sudden increase of a few race populations also causes the outbreak

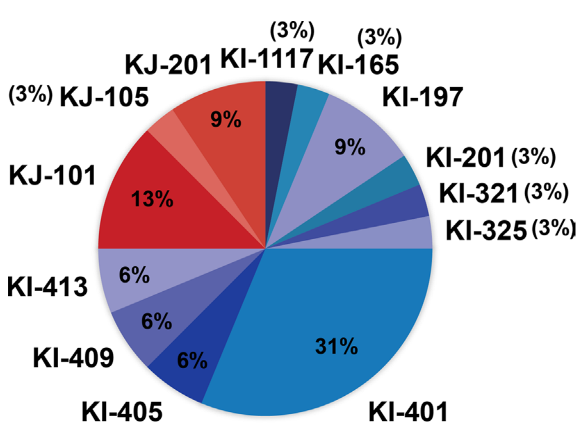

Fig. 2. KJ and KI race differentiation of Jeonbuk isolates.

of rice blast disease in fields. Prolonged cultivation of single rice cultivars with a similar genetic background results in the race transition of rice blast fungus in fields. The breakdown of rice blast resistance by race transition had been reported in Tongil-type rice cultivars in 1978, Jinjubyeo in 1980, Yeongpungbyeo and Poongsanbyeo in 1984, Cheonmabyeo and Seonambyeo in 1987, and Ilpumbyeo and Jinmibyeo in 1993 (Han et al., 2001). Ten rice cultivars including Sindongjin and Dongjinchal were mainly grown in Jeonbuk province in 2021 (Supplementary Table 5). Sindongjin and Dongjinchal with less resistance to rice blast had been continuously grown in a large area of Jeonbuk province since they were developed in 1999 and 1998, respectively. In 2021, Sindongjin and Dongjinchal were cultivated in 73186 ha and 11755 ha, respectively, accounting for 66% and 11% of the total rice cultivation area. Therefore, there is a possibility that the race transition of rice blast fungus appears in Jeonbuk province.

The National Institute of Crop Science developed the Korean race differential system in 1987 and analyzed the race diversity of rice blast fungus (Han, 1995; Han et al., 1994, 2001; Kim et al., 2016; Lee et al., 1987). Korean race differential system comprises one Indica- (Tetep), three Tongil- (Taebaeg, Tongil, and Yushin), and four Japonica-type (Kanto51, Nongbaeg, Jinheung, and Nakdong) rice cultivars and differentiates the rice blast fungus as 15 KJ-races and 240 KI-races according to the patterns of the resistant reactions (Supplementary Table 6). To identify the race diversity of rice blast fungus in Jeonbuk province, 32 isolates were collected from the infected neck samples of Hopyeong and Sindongjin in Buan and Gunsan (Supplementary Table 7). Each isolate was obtained by isolating single spores from each lesion of the infected samples. For single spore isolation, spores were induced on the infected samples by placing them on a water agar medium (15 g agar powder in 1 liter) at room temperature for 24 h and spread on another water agar medium using the loop. Germinated single spores were isolated on potato dextrose agar or rice bran agar medium (2 g rice bran, 2 g sucrose, and 2 g agar powder in 1 liter) under the microscope and maintained at 26°C. The spore suspension of each isolate was inoculated on Korean differential rice cultivars. Spores were harvested from 10-day-old rice bran agar plates that induce spores by removing the aerial mycelia and further incubating for 3 days under UV light. A volume of 25 ml of spore suspension adjusted to 10^5 spores per ml in 250 ppm Tween 20 solution was sprayed onto 3-4 leaf stage of rice seedlings. Inoculated rice seedlings were placed into the greenhouse after incubating in a dew chamber at 26°C for 24 h under dark conditions. The resistant reactions were evaluated by scoring the disease severity from 0 to 5 following the International Rice Research Institute standard evaluation method at 7 days after inoculation (Bonman et al., 1986). The isolates were divided into 13 races including two KJ-races and 11 KI-races, and the ratio of the isolates belonging to KJ- and KI-races was 25:75 (Fig. 2, Supplementary Table 7). Among the isolates, the predominant isolates in 2021 were KI-401 (31%) and KJ-101 (13%), accounting for 3% and 22% in 2019 and 3% and 13% in 2020, respectively (Fig. 2). It suggests that the distribution of the rice blast races could change from year to year. However, it is difficult to understand the genetic characteristics of the Jeonbuk isolates only by the differentiation of KJ and KI races. Genetic characteristics of the isolates need to be further investigated to prevent more effectively and develop the resistant rice cultivars.

These results indicate that the weather conditions during the heading season, prolonged cultivation of susceptible rice cultivars, and constant transition of rice blast races in Jeonbuk province complexly contributed to the outbreak of panicle blast in Jeonbuk province in 2021.

Conflicts of Interest

No potential conflict of interest relevant to this article was reported.

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Electronic Supplementary Material

Supplementary materials are available at The Plant Pathology Journal website (http://www.ppjonline.org/).

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