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Damage Analysis of Rice Panicle Blast on Disease Occurrence Time and Severity

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The structural differences between healthy and diseased panicle necks caused by *Pyricularia oryzae* were observed using electron-microscope. In the diseased panicle neck, the infection hyphae of the rice blast pathogen grew through the sclerenchymatous fiber tissue and reached to the central internal lacuna. Since the pathogen grew through the sclerenchymatous fiber tissues, the vascular bundle composed with xylem and phloem had been destroyed and finally the nutrients from the leaf and stem were not able to be transported into the grains. Infection of panicle base by the blast pathogen until 20 days after heading caused more than 50% of yield loss in both Jinmibyeo and Chucheongbyeo. There was a positive correlation between incidence of the panicle blast and rice yield losses. The regression equations between incidence of the panicle blast and yield losses were y = –3.61+496.7 (R^2 = 0.70) in Jinmibyeo and y = –3.93+520.2 (R^2 = 0.82) in Juanbyeo. The panicle blast caused deterioration of grain quality. Healthy grain rate was reduced by increase of panicle blast infection.

Keywords : heading time, internode, panicle blast, rice quality, yield loss

Rice blast disease attacked by *Pyricularia oryzae* causes severe yield losses in temperate region (Ou, 1985). Some recent surveys confirm that blast remains among the most serious biotic constrains to yield in Korea. Infection of panicle base, branches and spikelet pedicels may occur together, or they may occur separately under some different conditions. When an middle, and the internal structure is examined, there is a large lacuna in the center. The outermost part of the internode is the silicified epidermis, and under it is sclerenchmatous tissue. An outer ring of many small vascular bundles occurs within the peripheral sclerenchyma, and in the corresponding places in the inner parenchyma, there is a ring of large vascular bundles. This bundle in the internode is enclosed by a vascular bundle sheath and has phloem in the outer part and xylem in the inner part (Hosikawa, 1989).

Panicle blast causes direct yield losses, since filling of the grains on infected panicles is poor at best. For this reason, panicle blast is the more serious phase of the blast disease (Goto, 1965). Quantification of yield of rice blast disease requires information on specific mechanisms of disease damage effects. The spectacular yield reducing effects are caused by panicle blast which reduces the thousand grain weight, the percentage of ripe spikelets, and the percentage of fully mature grains (Teng et al., 1990). Panicles infected near the neck may break causing complete yield loss. The earlier the time of panicle infection, the greater the losses (Nutter, 1990). Infection of the stem nodes may cause the death of all plant parts above the point of infection. It may also cause a complete yield loss. The usual way to estimate panicle blast in yield loss studies has been percentage blasted panicles. Assesment of rice yield loss according to panicle blast can be used to establish economic thresholds and refers to any action to blast management in field.

Changes of internal structure of diseased panicle neck caused by rice panicle blast

Since rice blast pathogens destruct the plant tissues, the water or nutrient can not be transported into rice grains and resulted in the rice panicle blast. In order to investigate the changes of the diseased tissues, the structural differences between healthy and diseased panicle necks were observed using electron-microscope.

Ilmibyeo were grown in the paddy field until heading time. They were transferred into the greenhouse, five days after heading. KJ-301 race of *Pyricularia oryzae* was incubated in Petri dishes contained with oatmeal agar medium at 25°C in an incubator. The rice neck tissue samples were cut as long as 5cm and laid straightly in the Petri dishes where the hyphae of *P. oryzae* were grown. Rice tissue samples were cut out from inoculated and noninoculated panicles three days after inoculation. The

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inoculated tissues were dissected and fixed for scanning electron microscopy. Specimens for scanning electron microscopy were fixed in 2.5% Karnovsky's fix solution at 4°C overnight, washed in 0.05 M cacodylate buffer (pH 7.2) three times every 10 minutes, and rinsed in the same buffer. The tissues were post fixed with 1% osmium tetraoxide at 4°C for 2 hr, dehydrated in a graded alcohol series (50-100%) and subjected to critical point drying after replacing by isoamyl acetic acid. After drying, the tissues were put on specimen holder and coated with gold using Ion Sputter and observed through SEM (Hitach S-2460N, Japan).

The cross-section of rice panicle neck was a round shape and the underneath of the silicated epidermal cell was a sclerenchymatous fiber tissue (Fig. 1). The central internodal lacuna was surrounded by 10-12 large vascular bundles followed by small vascular bundles. Vascular bundle was composed with inner part xylem and outer part phloem. Small vascular bundle had a simple shape with small and thin conductive tissues. In the diseased panicle neck, the infection hyphae of the rice blast pathogen grew through the sclerenchymatous fiber tissue and reached to the central internal lacuna (Fig. 2). Since the pathogen grew through the sclerenchymatous fiber tissues, the vascular bundle composed with xylem and phloem had been destroyed and finally the nutrients from the leaf and stem were not able to be transported into the grains.

Rice panicle neck tissues infected with the blast pathogen have been studied by light microscopy (Horino et al., 1986), fluorescence microscopy (Koga et al., 1988) and scanning electron microscopy (Koga et al., 1991). The previous microscopic approaches had proved to be difficult to get good results. Koga (1994) carried out to clarify the mode of penetration of blast fungus into the epidermis of panicle neck. The present study provides information about the possible cause of the neck blast symptoms formed on panicle necks infected with the blast pathogen.

Estimation of rice yield loss according to panicle blast occurrence time in the field

When the neck blast symptom early was developed after

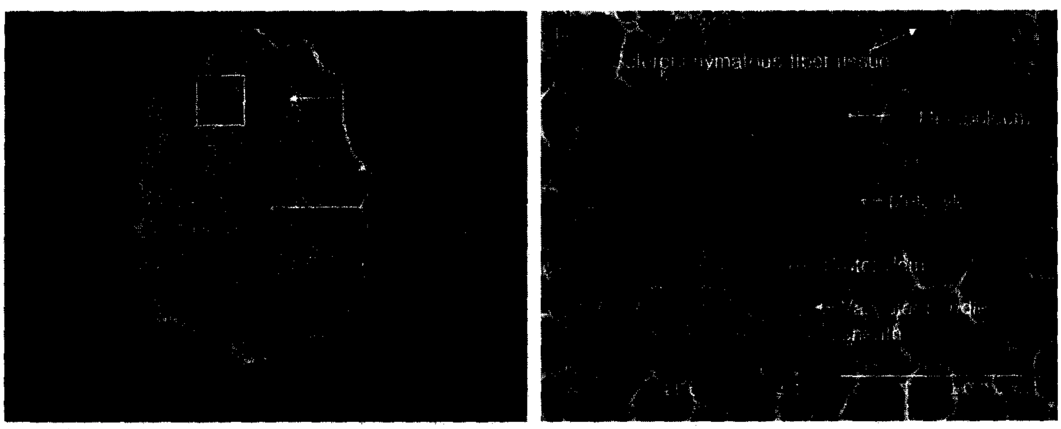

Fig. 1. Internal structure of the healthy rice panicle neck of Ilmibyeo ten days after heading of rice in the paddy field. **A**; Cross section of a healthy panicle neck, **B**; structure of large vascular bundle.

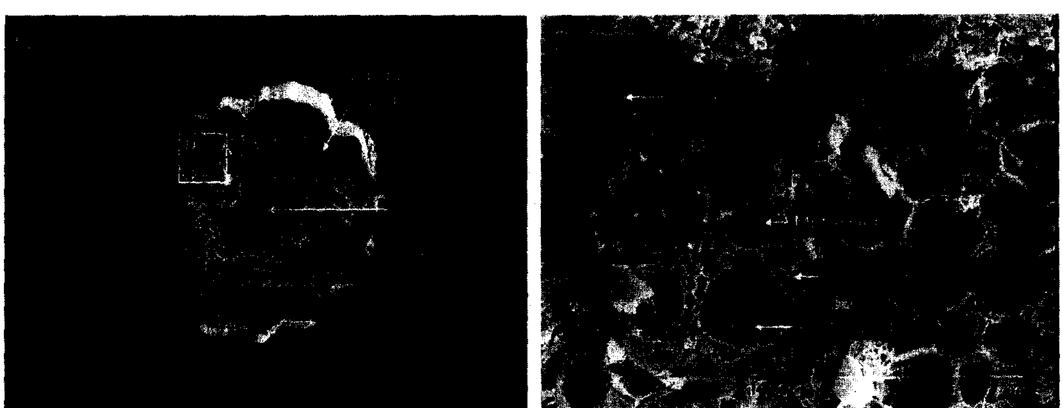

Fig. 2. Internal structure of the diseased rice panicle neck of Ilmibyeo at ten days after heading in the paddy field. C; Cross section of a diseased panicle neck, D; Structure of large vascular bundle.

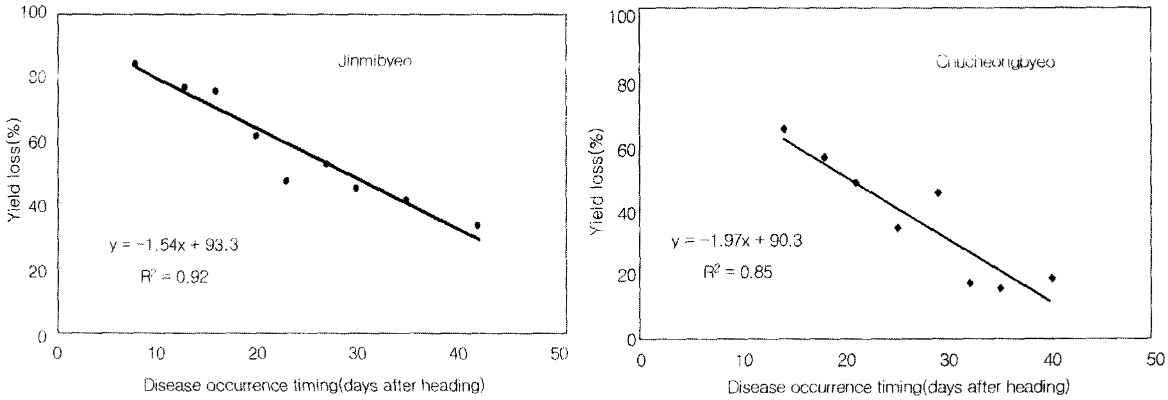

Fig. 3. Regression equation of rice yield loss according to disease occurrence timing of the panicle blast in Jinmibyeo and Chucheongbyeo. Correlation coefficients between yield loss and days after heading were r = –0.96* in Jinmibyeo and r = –0.92* in Chucheongbyeo. *Values are significantly different ($P < 0.05$).

Table 1. Weights of 1,000 grains according to disease occurrence time of the panicle blast in Jinmibyeo at Icheon in 2000

Date of symptom observed[a]	Weight of 1,000 grains (g)[b]	Comparative yield ratio (%)
Aug. 9	7.11	29.6
Aug. 14	8.03	33.5
Aug. 17	6.19	25.8
Aug. 19	12.54	52.3
Aug. 25	19.08	79.5
Sep. 4	20.02	83.5
Sep. 11	21.09	87.9
Control (Healthy)	23.99	100

[a] Heading date was July 31 and rice panicles were harvested on September 15.
[b] Regression equation of 1,000 grains weight according to disease occurrence time of the panicle blast was $y = 0.50x + 1.9$ ($R^2 = 0.82$).

Table 2. Weights of 1,000 grains according to disease occurrence time of the panicle blast in Chucheongbyeo at Icheon in 2000

Date of symptom observed[a]	Weight of 1,000 grains (g)[b]	Comparative yield ratio (%)
Sep. 7	13.78	57.3
Sep. 11	20.70	86.1
Sep. 18	22.39	93.1
Sep. 21	22.26	92.6
Sep. 27	22.33	92.9
Control (Healthy)	24.04	100

[a] Heading date was August 17 and rice panicles were harvested on October 5.
[b] Regression equation of 1,000 grains weight according to disease occurrence time of the panicle blast was $y = 0.37x + 9.0$ ($R^2 = 0.62$).

heading, the yield loss increased very high. Early infected panicles were dried or broke and white head except the chaff. But late infected panicles had only a small symptom and they had full grains. The symptom of rice panicle blast developed at 9th day in Jinmibyeo and 21th day in Chucheongbyeo after heading on the paddy field. Panicle base blast within 20 days after heading caused more than 50% of yield losses in both Jinmibyeo and Chucheongbyeo (Fig. 3). Later infection of panicle base 30 days after heading caused about 45% of yield losses in both Jinmibyeo and Chucheongbyeo. Yield loss of Jinmibyeo was greater than that of Chucheongbyeo when symptoms observed at the same days after heading. Jinmibyeo, an early maturing cultivar, is more sensitive in neck blast and has lower field resistance than Chucheongbyeo, a mid-late maturing cultivar (Choi et al., 1991; Choi et al., 1996).

One thousand grain weight of Jinmibyeo were 7.11 g based on rough grain and when infected 9 days after heading, respectively (Table 1). Those of Chucheongbyeo was 13.78 g based on rough grain when infected at 21 after heading (Table 2). Comparing the yield loss and 1,000 grain weight, when rice panicle necks were infected in the early stage after heading by neck blast, yield losses is much more severe.

Estimation of rice yield loss and quality according to panicle blast severity in the field

Rice blast disease has been considered as a serious constraint to rice yield (Awoderu et al., 1992; Chien, 1976; Koizumi et al., 1993). The efficient application of blast disease management program is up on having accurate and precise information on disease incidence and on the relationship between disease intensity and yield loss (Nutter, 1990; Tsai, 1988). Our results were obtained from field studies conducted in 2001 at Icheon Experimental Station.

There was a positive correlation between incidence of the panicle blast and rice yield loss. The regression equations between incidence of the panicle blast and yield loss were

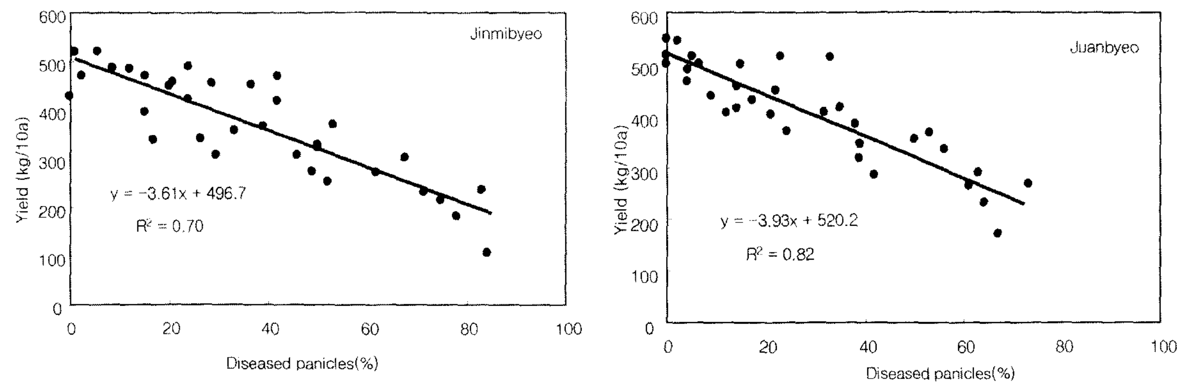

Fig. 4. Regression equation of rice yield according to the panicle blast incidence in Jinmibyeo and Juanbyeo at Icheon in 2001. Correlation coefficients(r) between yield and percentage of diseased panicles were –0.84* in Jinmibyeo and –0.91* in Juanbyeo. *Values are significantly different (P < 0.05).

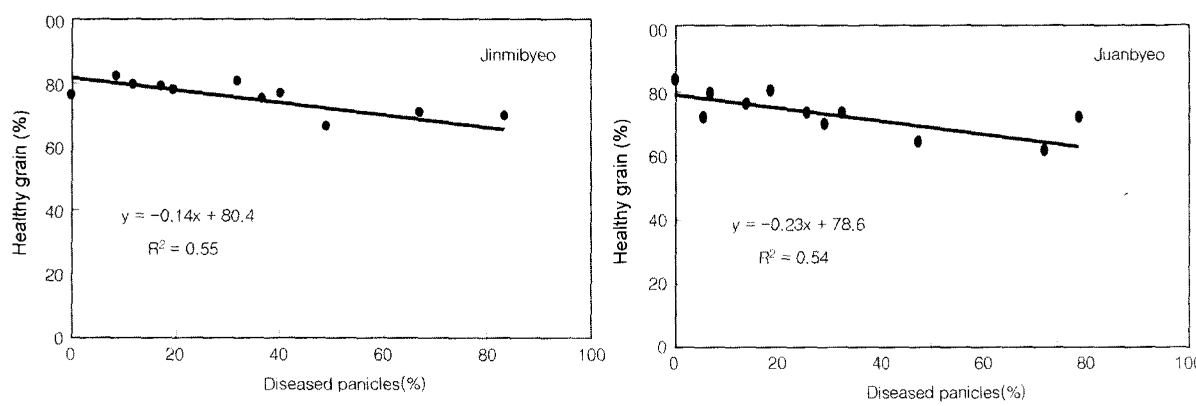

Fig. 5. Regression equation of the healthy grain rate according to the panicle blast incidence in Jinmibyeo and Juanbyeo at Icheon in 2001. Correlation coefficients(r) between healthy grain rate and percentage of diseased panicles were –0.74* in Jinmibyeo and –0.74* in Juanbyeo. *Values are significantly different (P < 0.05).

$y = -3.61+496.7$ ($R^2 = 0.70$) in Jinmibyeo and $y = -3.93 +520.2$ ($R^2 = 0.82$) in Juanbyeo (Fig. 4). Correlation coefficient(r) between yield loss and diseased panicles were –0.84 in Jinmibyeo and –0.91 in Juanbyeo, respectively.

The panicle blast caused deterioration of grain quality (Filippi et al., 1998; Tatsuta et al., 1983). Healthy grain rate was reduced by increase of panicle blast infection. Juanbyeo was more affected than Jinmibyeo in the deterioration of rice quality (Fig. 5). The regression equation between the panicle blast incidence and healthy

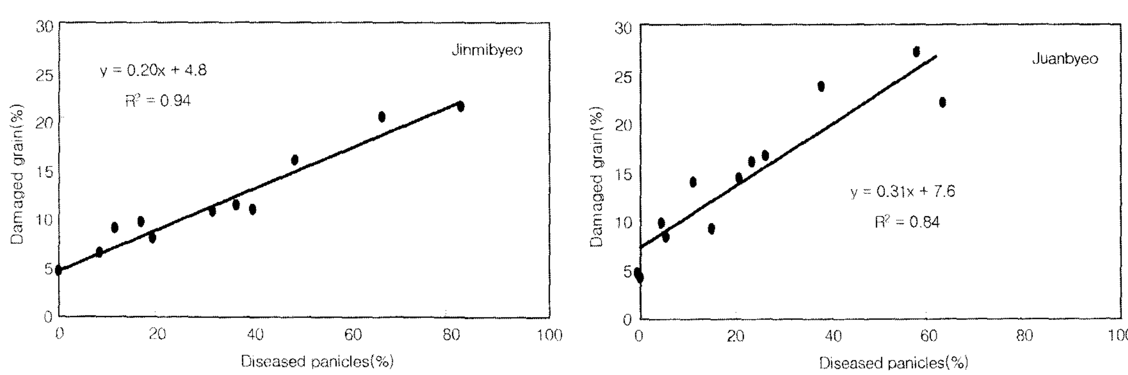

Fig. 6. Regression equation of the damaged grain rate according to the panicle blast incidence in Jinmibyeo and Juanbyeo at Icheon in 2001. Correlation coefficients(r) between damaged grain rate and percentage of diseased panicles were 0.97* in Jinmibyeo and 0.92* in Juanbyeo. *Values are significantly different (P < 0.05).

grain rate were y = −0.14x+80.4 (R^2 = 0.55) in Jinmibyeo and y = −0.23x+78.6 (R^2 = 0.54) in Juanbyeo. There was negative correlation between the panicle blast incidence and the healthy grain rate and correlation coefficient(r) were −0.74 both in Jinmibyeo and Juanbyeo. Meanwhile, damaged grain ratio increased according to the increase of the panicle blast incidence (Fig. 6). The correlation coefficients between disease incidence and percent of damaged grains were 0.97 with the regression equations y = 0.20x+4.8 (R^2 = 0.94) in Jinmibyeo and 0.92 with y = 0.31x+7.6 (R^2 = 0.84) in Juanbyeo. However, percentage of green kerneled rice and broken rice did not increase according to the increase of the panicle blast incidence.

Rice blast is considered an important disease, capable of causing severe losses up to 100% in farmers' fields. Padmanabhan (1965) reported that some states in India suffered a one percent of rice yield loss in 1960-1961, within a range 5-10% by rice blast disease. Losses due to blast were estimated at 8.4% in 1980 and 14.0% in 1981 in China (Teng et al., 1990). But the most spectacular yield reducing effects are caused by panicle blast (Ou, 1985; Torres et al., 1988). Rice panicle blast reduces the yield, the 1,000 grain weight and the percentage of fully mature grains (Goto, 1965; Kang et al., 1979). It also increases the faction of chalky kernels, thus lowering the grain quality (Takasaki, 1988; Torres et al., 1991). Padmanabhan (1965) gave equation for estimating losses as follows; one % neck blast = 0.45% yield loss. Katsube et al. (1970) estimated using the equation of a percentage loss = 0.57^{**}(percentage blasted nodes, 30 days after heading). In these studies, we obtained the equation between incidence of the panicle blast and yield loss y = −3.61+496.7 (R^2 = 0.70) in Jinmibyeo and y = −3.93+520.2 (R^2 = 0.82) in Juanbyeo and the regression equation between incidence of the panicle blast and healthy grain rate y = −0.14x+80.4 (R^2 = 0.55) in Jinmibyeo and y = −0.23x+78.6 (R^2 = 0.54) in Juanbyeo. The interaction between panicle blast incidence and yield loss resulted in better understanding of yield reduction in rice due to panicle blast. The above model can be used to estimate yield reduction due to panicle blast.

Crop losses assesment can be used to establish economic thresholds (Takeuchi, 1997). The information can provide a better understanding of the relative severity of disease in rice. Economic threshold level of the panicle blast was calculated to determine chemical application using yield losses model of Jinmibyeo and Juanbyeo. Economic threshold level of the panicle blast in the two rice cultivars was 2%. When the panicle blast occurred more than 3%, income reduction exceeded the cost for general pest control. When the panicle blast occurred more than 13% in Jinmibyeo and 12% in Juanbyeo, income reduction caused by yield loss exceeded the farmer's labor cost. If the panicle blast occurred more than 38% in Jinmibyeo and 35% in Juanbyeo, income reduction exceeded the cost for rice management. As a conclusion chemical application to control the panicle blast should be carried, when the panicle blast incidence become higher than 2%. Economic threshold level can change according to growth stage of target crop, level and cost of fertilizer, pesticide and labor, yields and price of products. Above the thresholds, control may be profitable, if its costs do not exceed benefits.

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