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# A novel method for controlling rice blast disease using fan-forced wind on paddy fields

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ABSTRACT

Rice blast disease is one of the obstacles of rice production not only in Japan but throughout rice producing countries. The effects of fan-forced wind on the incidence of rice blast disease were studied in two successive seasons. Electric fans (5 KW, 110-cm blade diameter) set on the ridge of paddy fields at a height 5 m from the ground level were used to artificially generate wind. In season 1, the fan operated twice daily for 30 min periods at 11:00 PM and 4:00 AM from June 15 to September 1. The blocks of the paddy fields were divided into 6 zones according to wind speed and distance from the fan. The wind speed ranged from 2.0 to >7.3 m/s. The incidence of both rice leaf and panicle blast was significantly lower in the zones receiving wind between 2.6 and 7.3 m/s; however, the zone that received a velocity >7.3 m/s was severely affected by leaf and panicle blast. The zone that received the a wind speed of 2.6 m/s or lower exhibited an inefficient reduction of leaf and panicle blast disease, but it was better than in the control fields. In season 2, a wind-forced fan was applied from June 16 to September 9, with the velocity adjusted between ca. 3.0 and 6.0 m/s. The incidence and severity of leaf and panicle blasts (chuff, rachis-branch and neck blast) were efficiently reduced in the wind-treated fields. Fan-forced wind was more effective than the application of conventional chemical fungicides for controlling rice blast disease. These data demonstrate the potential of fan-forced wind for controlling rice blast disease.



## 1. Introduction

Japan is the ninth largest producer of rice in the world. The rice seasons in the northern, central and southern parts of Japan last from May–June to September–October, from April–May to August–October and from April–May to August–September, respectively. Approximately 6000 years ago, rice occupied a prominent place in the history, society, and political economy of Japan (Hsu, 1994). Improved varieties of japonica rice are grown in almost all prefectures in Japan.

Rice is susceptible to diseases whenever it is grown. Rice blast disease, caused by *Pyricularia grisea* (Cooke) Sacc., teleomorph *Magnaporthe grisea* (Herbert) Barr, is one of the most prevalent diseases of rice plants (Katsube and Koshimizu, 1970; Plant Protection Annual 1960–1997; Rossman et al., 1990) and has been found in more than 85 countries (Kato, 2001). The management of blast disease had been extensively investigated; by using antagonistic bacteria, such as strains of *Pseudomonas fluorescens*, *Bacillus polymyxa* (Karthikeyan and Gnanamanickam, 2008), *Bacillus licheniformis* (Tendulkar et al., 2007) and *Streptomyces* sp. PM5 (Prabavathy et al., 2006); by using disease-resistant cultivars (Koizumi and Kato, 1987; Tokunaga, 1965; Villareal et al., 1981); by reducing nitrogen fertilizers, conditioning paddy soil, practicing crop hygiene, using agricultural chemicals mainly as seed treatments (Teng, 1994; Yokoyama, 1981) and by using organic manures (Obilo et al., 2012). All of these previous methods attenuated disease symptoms in either seedbed or glasshouse trials. However, their effectiveness has not been demonstrated in large-scale, long-term field experiments.

Focusing on the control of a disease usually involves targeting the infection process of the plant by the pathogens (Barksdale and Asai, 1961; Hashioka, 1950; Hemmi and Abe, 1931; Hemmi and Imura, 1939; Misawa and Matsuyama, 1960; Suzuki, 1969b; Yoshino, 1979). Penetration by the pathogen is greatly influenced

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by the temperature and the period for which the leaf blade remains wet during infection. Therefore, the severity of rice blast disease outbreaks is strongly influenced by the prevailing weather conditions, i.e., rain, wind, temperature, and sunlight (Hashimoto et al., 1984; Hemmi and Abe, 1931; Kato and Diamond, 1966; Ono and Suzuki, 1959; Ou et al., 1974; Suzuki, 1969a). The prediction of rice leaf blast outbreaks has been investigated by the use of computer simulations based on these causal factors (Hashimoto et al., 1984; Ishiguro and Hashimoto, 1991; Koshimizu, 1988; Teng et al., 1991). The use of resistant cultivars and agricultural chemicals are the only effective control measures currently available for rice blast; no other effective control measures have been found (Teng, 1994; Yokoyama, 1981).

Among various weather factors, wind has the potential to reduce the severity of rice blast, possibly by reducing both the number of spores adhering to plant surface and the period the leaf remains sufficiently wet to permit infection (Adachi, 1981; Misawa and Matsuyama, 1960; Schrodter, 1960; Suzuki, 1969b). This suggests that artificially created wind might also reduce the severity of rice blast. However, no report has discussed the potential use of fan-forced wind to reduce rice blast. The influences of fan-forced wind on the formation of guttation droplets on rice leaves in paddy fields as well as on the removal of dew droplets were investigated in an associated study. Levels of dew droplets decreased rapidly as soon as the blowing of wind onto the rice hills commenced. Dew weights remained lower in wind-treated paddy fields than in the controls. A few rotations (Barksdale and Asai, 1961) of fan-forced wind at 3.2 m/s or more was sufficient to remove guttation and dew droplets and reduce subsequent dew formation (unpublished data). The present study was carried out to determine the appropriate strength and the duration of artificially generated wind that can effectively reduce the severity of rice blast disease compared with the use of fungicide. For this purpose, large electric fans capable of directing wind to large areas in the paddy field were constructed. The leaves and panicles of rice were evaluated to determine the appropriate wind-force and its period of application that could be effectively used to control rice blast disease.

## 2. Materials and methods

Three paddy fields located in the mountainous area in Shirakawa-cho, Gifu Prefecture (460 m above sea level) in the main island of Japan were used in the study.

### 2.1. Season 1

#### 2.1.1. Area of study

A paddy field (60 m × 30 m) with a history of serious outbreaks of rice blast, hereafter referred to as the **G1** field, and a terraced paddy field (50 m × 25 m) with a moderate level of rice blast, hereafter referred to as the **T** field, were used in this experiment (Fig. 1). Paddy fields adjacent to the west side of the G1 field and to the east side of the T field were used as controls with no treatment. Seedlings of the "Kinuhikari" cultivar were planted (30 cm line interval and 18 cm hill interval) in the fields on May 25.

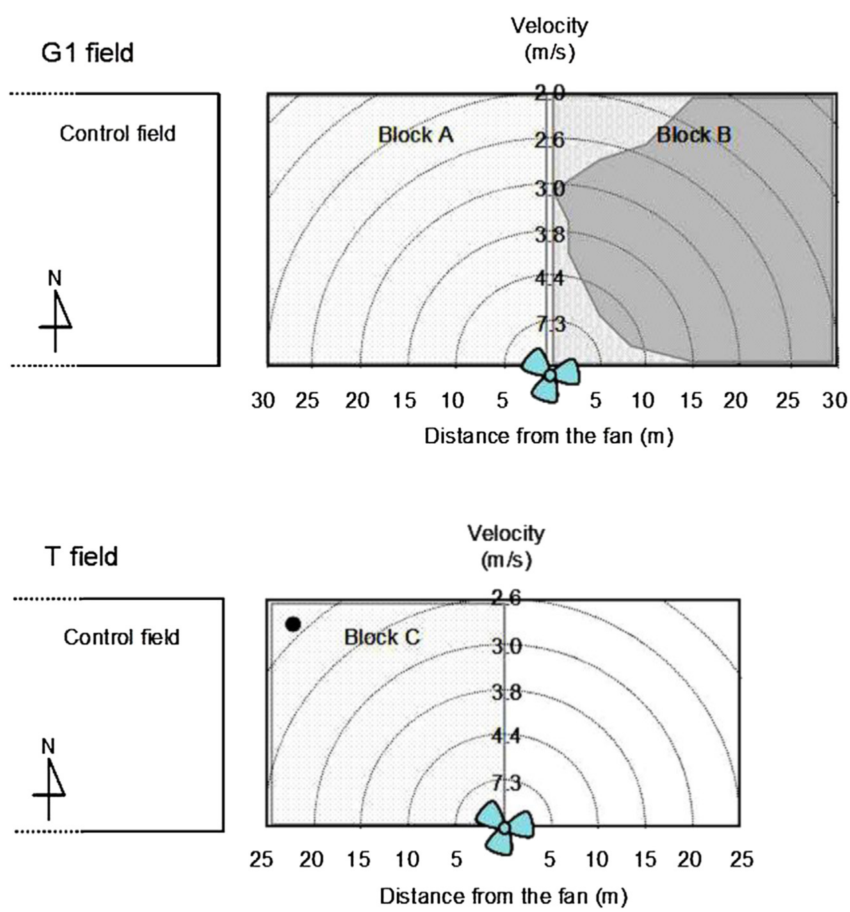


**Fig. 1.** A diagrammatic sketch depicting G1 and T fields used in season 1; G1 field consists of block A (left) and block B (right). The highlighted section in block B indicates the shade by the trees. The Control field locates on the west side of block A. The T field consists of Block C (left) and the Control field locates on the east side of block C. The symbol ● indicates the zone which is out of the blowing range.

**Table 1**
Wind velocity and distance from fan in each zone of the blocks.

| Zone number | Distance from fan (m) | Wind velocity (m/s) |
|---|---|---|
| 1 | 0–5 | 7.3 |
| 2 | 5–10 | 4.4 |
| 3 | 10–15 | 3.8 |
| 4 | 15–20 | 3.0 |
| 5 | 20–25 | 2.6 |
| 6 | 25–30 | 2.6 |

*2.1.2. Fan-forced wind*

A large electric fan (180° rotation range, 5 KW, 110 cm blade diameter, 4020 $m^3$/min airflow, Matsushita Seiko Engineering Co., Ltd, Japan) set atop a 5 m pillar with a depression angle of 30° was installed at the edge of the each field (Fig. 1). The fan operated 2 times daily for 30 min each starting at 11:00 PM and 4:00 AM, respectively, from June 15 to September 1.

The G1 field was divided into two blocks, A and B, on the east and west sides of the fan, respectively, to analyze the correlation between wind velocities and both the severity and incidence of rice blast (Fig. 1). In the T field, a block on the east side of the fan was designated as block C (Fig. 1). The wind velocity was measured 80 cm above the ground with an Anemomaster Wind Speed Meter®, Nicon Kagaku Kogyo, Japan. The blocks were divided into 6 zones according to wind velocity and distance from the fan (Table 1, Fig. 1). The wind velocity ranged from >7.3, 7.3–4.4, 4.4–3.8, 3.8–3.0, 3.0–2.6 and 2.6–2.0 m/s in the zones at distances of 0–5 m, 5–10 m, 10–15 m, 15–20 m, 20–25 m and 25–30 m from the fan, respectively. Both blocks A and C received direct sunlight from morning to evening, while block B was shaded in the morning (especially in zones 5 and 6) until 8:30 and 9:00 AM in June and August, respectively. The fan operated 6 rotation cycles in each 30 min period. The period of the wind was received at all zones of the blocks was the same and was 60 s in each cycle.

*2.1.3. Evaluation of rice blast disease severity and incidence*

The incidence of leaf blast was evaluated by counting the infected hills in 100 randomly sampled hills in the different zones of each block. The incidence of panicle blast was measured by counting the infected panicles in 400 randomly sampled panicles in each zone as previously described. The severity of panicle blast disease was calculated according to the following formula: Disease severity $= (0 \times a + 1 \times b + 2 \times c + 3 \times d + 4 \times e) / 4 \times (a + b + c + d + e) \times 100$, where "a" is the number of uninfected panicles, "b" is the number of panicles in which only one third was infected, "c" is the number of panicles in which one to two thirds were infected, "d" is the number of panicles in which over two thirds of the panicle were infected, and "e" is the number of totally infected panicles. The incidence of leaf and panicle blast disease was investigated weekly starting July 4 and ending September 7.

## 2.2. Season 2

In season 1, the reduction in incidence and severity of rice blast disease was obvious in zones 2–5, which received a wind velocity of 2.6–7.3 m/s. However, zones 1 and 6, which received wind velocities >7.3 m/s and <2.6 m/s, did not exhibit an adequate reduction in disease incidence and severity. Therefore, the aim of this study in season 2 was to investigate the inhibitory effect of wind velocity adjusted to ca. 3–6 m/s on rice blast disease. A further goal was to compare the reduction effect of wind application with the conventional use of chemical fungicides in controlling rice blast disease.

*2.2.1. Area of study*

A paddy field (45 m × 15 m) with a history of low occurrence of rise blast disease, hereafter referred to as the **G2** field, was used in this experiment (Fig. 2). The fields adjacent to **G2** on the north and the west sides were used as Control fields C1 and C2, respectively. "Yamahikari" cultivar seedlings were planted in these fields on May 26. **G2**, C1 and C2 were further divided into 14, 4 and 3 blocks, respectively (Fig. 2) and each block was studied to evaluate the severity and incidence of rice blast disease as previously described.

*2.2.2. Fan-forced wind*

The fan setting was the same as described for season 1 except that 2 fans were used, one fixed in the central ridge and the other in the right corner of the G2 field (Fig. 2). The fan had a depression angle of 45° and operated with a rotation range of 90°. The wind velocity was adjusted and ranged from 3 to 6 m/s in different zones with a period of 30–60 s in each stroke. The actual wind velocity in each zone ranged from 2 to 6 m/s (Table 2). These fans were operated twice daily for 30 min during each period starting at 11:00 PM and 4:00 AM from June 16 to September 9.

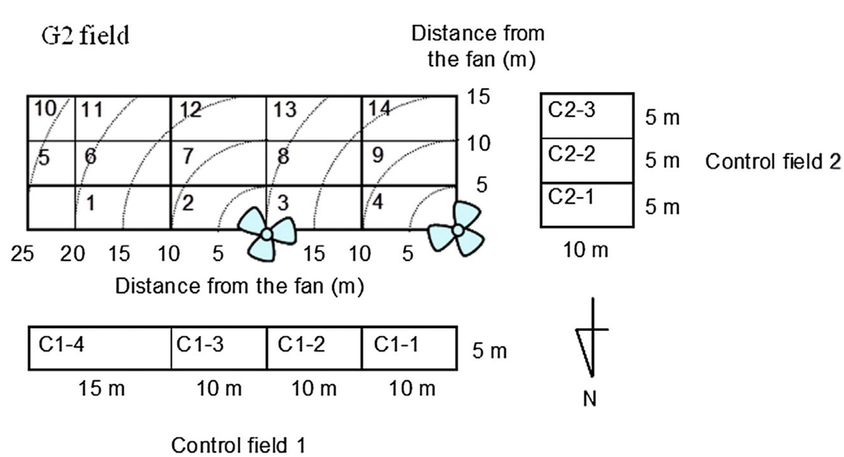


**Fig. 2.** A diagrammatic sketch depicting G2 field used in season 2. The blocks numbered from 1 to 14 were exposed to the wind treatment. The wind velocity was ranged from 0 to 6 m/s among blocks. The Control fields locate on the north and west side of G2 field (Control field 1 and Control field 2, respectively). The zones numbered from C1-1 to C1-4 and from C2-1 to C2-3 indicate research blocks of the Control fields.

**Table 2**
Disease incidence (%) of leaf and panicle blast in rice in G2 field under wind treatment (Experiment 2).

| Blocks | Leaf blast | | | | Panicle blast | | | | | | Velocity (m/s) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | July 9 | July 14 | Aug 2 | Aug 11 | September 11 | | | September 30 | | | |
| | | | | | Chuff blast | Rachis branch blast | Total | Rachis branch blast | Neck blast | Total | |
| **Fields exposed to wind**[a] | | | | | | | | | | | |
| 1 | 0.0 | 0.0 | 0.0 | 0.0 | 5.0 | 0.0 | 5.0 | 3.0 | 3.0 | 6.0 | 4–6 |
| 2 | 0.0 | 0.0 | 0.0 | 0.0 | 3.0 | 1.0 | 4.0 | 4.0 | 2.0 | 6.6 | 6 |
| 3 | 0.0 | 0.0 | 0.0 | 0.0 | 8.0 | 0.0 | 8.0 | 4.0 | 4.0 | 8.0 | 2–6 |
| 4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.0 | 0.0 | 2.0 | 2–6 |
| 5 | 0.0 | 0.0 | 0.0 | 0.0 | 3.0 | 0.0 | 3.0 | 2.0 | 1.0 | 3.0 | 2–4 |
| 6 | 0.0 | 0.0 | 0.0 | 0.0 | 2.0 | 0.0 | 2.0 | 3.0 | 0.0 | 4.0 | 3–5 |
| 7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 1.0 | 2.0 | 6 |
| 8 | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 0.0 | 4.0 | 4.0 | 8.0 | 12.0 | 2–6 |
| 9 | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 0.0 | 4.0 | 3.0 | 2.0 | 5.0 | 6 |
| 10 | 0.0 | 0.0 | 0.0 | 0.0 | 3.0 | 0.0 | 3.0 | 3.0 | 7.0 | 10.0 | 2–3 |
| 11 | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 0.0 | 4.0 | 9.0 | 0.0 | 9.0 | 2–5 |
| 12 | 0.0 | 0.0 | 0.0 | 0.0 | 3.0 | 0.0 | 3.0 | 10.0 | 1.1 | 11.0 | 4–6 |
| 13 | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 0.0 | 4.0 | 6.0 | 1.1 | 7.0 | 3–6 |
| 14 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.0 | 1.0 | 10.0 | 13.0 | 23.0 | 3–6 |
| Average | 0.0 | 0.0 | 0.0 | 0.0 | 3.1 | 0.1 | 3.2 | 4.6 | 3.1 | 7.7 | – |
| Standard error | 0.0 | 0.0 | 0.0 | 0.0 | 0.55 | 0.07 | 0.56 | 0.80 | 1.02 | 1.45 | – |
| **Control field 1**[a,b] | | | | | | | | | | | |
| 1 | 0.0 | 0.0 | 0.0 | 0.0 | 21.0 | 1.0 | 22.0 | 7.0 | 45.0 | 52.0 | –[c] |
| 2 | 0.0 | 3.0 | 3.0 | 3.0 | 44.0 | 1.0 | 45.0 | 22.0 | 33.0 | 55.0 | – |
| 3 | 0.0 | 0.0 | 0.0 | 0.0 | 50.0 | 0.0 | 50.0 | 6.0 | 67.0 | 73.0 | – |
| 4 | 0.0 | 0.0 | 0.0 | 0.0 | 19.0 | 4.0 | 23.0 | 16.0 | 13.0 | 29.0 | – |
| Average | 0.0 | 0.75 | 0.75 | 0.75 | 33.5 | 1.5 | 35.0 | 12.8 | 39.5 | 52.3 | – |
| Standard error | 0.0 | 0.75 | 0.075 | 0.75 | 7.90 | 0.866 | 7.29 | 3.82 | 11.30 | 9.03 | – |
| **Control field 2**[a] | | | | | | | | | | | |
| 1 | 0.0 | 5.0 | 10.0 | 13.0 | 35.0 | 10.0 | 45.0 | 23.0 | 56.0 | 79.0 | – |
| 2 | 0.0 | 4.0 | 9.0 | 10.0 | 21.0 | 3.0 | 24.0 | 17.0 | 32.0 | 49.0 | – |
| 3 | 0.0 | 3.0 | 15.0 | 21.0 | 32.0 | 18.0 | 50.0 | 18.0 | 66.0 | 84.0 | – |
| Average | 0.0 | 4.0 | 11.3 | 14.7 | 29.3 | 10.3 | 39.7 | 19.3 | 51.3 | 70.6 | – |
| Standard error | 0.0 | 0.58 | 1.86 | 3.28 | 4.26 | 4.33 | 7.97 | 1.86 | 10.09 | 10.93 | – |

[a] Tricyclazole dusting powder was applied to the seedlings at seeding stage prior to transplanting to the field.
[b] The Control field 1 was sprayed with tricyclazole granules, probenazol granules, kasugamicine·phthalide dusting powder and EDDP·phthalide dusting powder in order to control rice blast disease.
[c] Wind treatment was not applied.

*2.2.3. Evaluation of rice blast disease severity and incidence*

The incidence of leaf blast was evaluated by counting the number of infected hills in 100 randomly sampled hills from each block of the14 blocks in G2 field on July 9 and 14 and August 2 and 11. The incidence of leaf blast in the C1 and C2 fields was also investigated. The incidence of panicle blast was investigated in each block of the G2 field as well as the Control fields. The number of infected panicles with chuff blast, rachis-branch blast or neck blast was recorded in 200 randomly sampled panicles on September 11 and 30.

## 2.3. Use of chemicals

Tricyclazole granules were applied to seedlings in the raising box (505 × 360 × 107 mm) (50 g/box) used for planting the G2, C1 and C2 fields to prevent leaf blast. Conventional chemical fungicides; probenazol granules (4 kg/10a), kasgamycin phthalide dusting powder (4 kg/10a) and EDDP phthalide dusting powder (4 kg/10a) were sprayed over the C1 field using an agrochemical spraying vehicle on June 27, July 25 and August 24, respectively.

# 3. Results

## 3.1. Season 1

*3.1.1. G1 field*

In the Control field, rice leaf blast was first observed on June 28, and its incidence reached 86% on July 12 and 19 (Fig. 3A). The incidence of leaf blast increased to 100% on July 26. However, leaf blast disease was not detected until July 12 in block A of the G1 field. Although, the incidence of the disease in zone 6 increased to 38% on August 3, in the other zones, especially 1 and 2, it remained low, i.e., 7% and 5%, respectively. Similarly, the incidence of leaf blast in block B remained below 20% throughout the experiment except for zones 5 and 6, where the incidence greatly increased to 42% and 91%, respectively, on August 3.

The incidence of rice panicle blast was 49% in the Control field on August 21; however, it was below 25% in all zones of blocks A and B of the G1 field, except for zone 6 in block B, where it was 50%. The incidences of panicle blast were 2% and 6% in zone 3 and 6% and 4% in zone 2, in blocks A and B, respectively (Fig. 3B). The incidence of panicle blast reached 96% on September 7 in the Control field, while remaining lower than 50% in most zones in blocks A and B. The incidence of panicle blast increased to 81 and 96% in zones 1 and 6 in block B, respectively.

The severity of panicle blast disease in the Control field was 18, 42 and 57 on August 21 and 29 and September 7, respectively (Fig. 4). Except for zones 1 and 6 in block B, panicle blast severity was significantly lower than 22 in all zones of blocks A and B until September 7.

In the G1 field, the obvious reduction of the incidence and severity of both leaf and panicle blast was observed throughout the experiment in zones 2, 3, 4 and 5. The efficient effect of applying appropriate wind velocity on the reduction of rice blast disease was obvious in the paddy fields even under shade conditions as shown in block B.

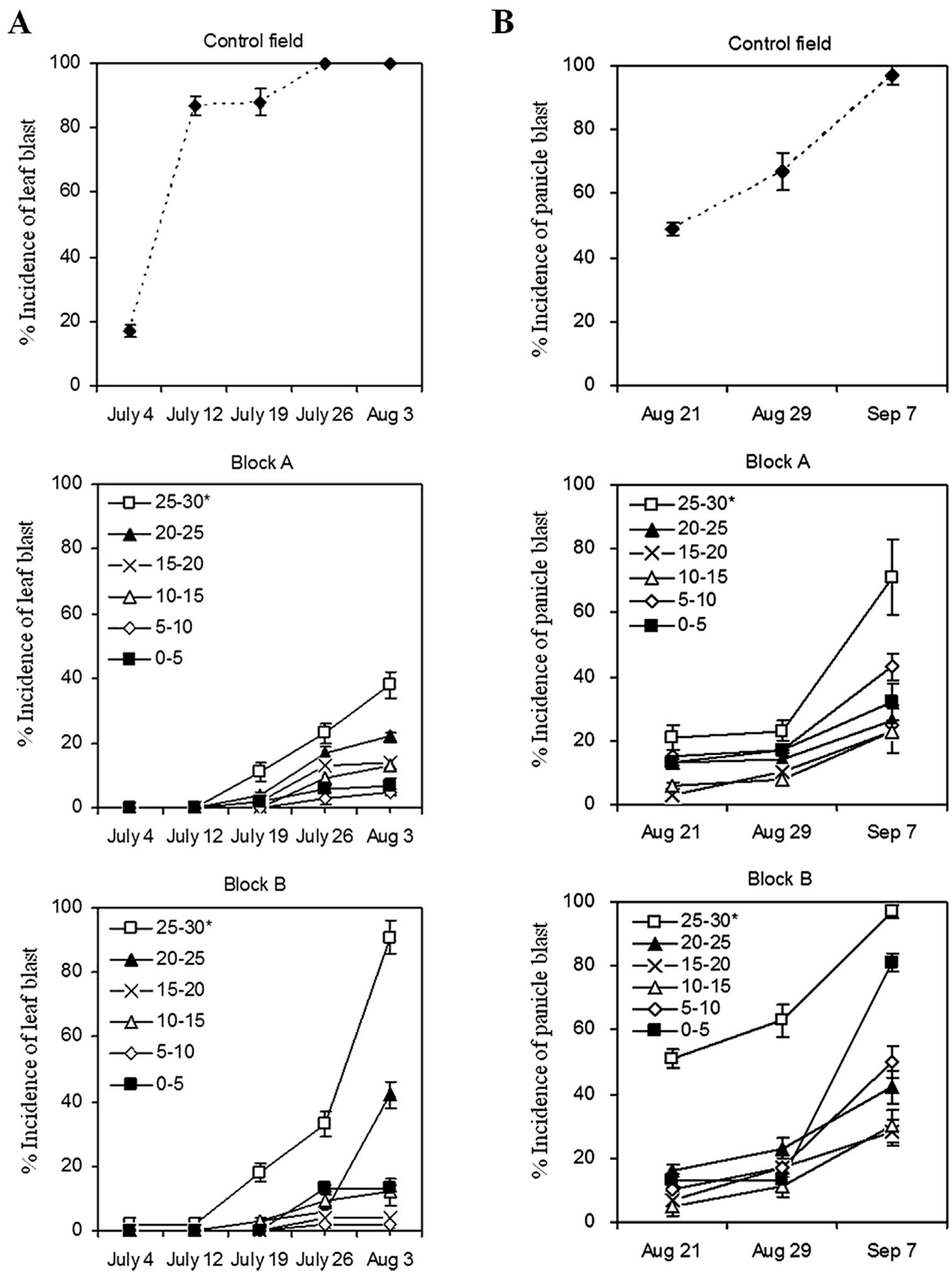


**Fig. 3.** Incidence of rice leaf (A) and panicle (B) blast diseases in Control field, block A and block B, respectively, in G1 field. *Distance (m) from the fan. Bars represent standard errors.

*3.1.2. T field*

The incidence of leaf blast disease was lower in the T field control (Fig. 5A) than that in the G1 field. The incidence of leaf blast disease in the Control field first appeared in 6% of the hills on July 12, which increased to 19.7% on July 26. Moreover, leaf blast was not noticed in zones 2 and 3 until August 3. In zones 1 and 4, the incidence of the disease was also very low, being 0.5% and 2%, respectively.

The incidence of panicle blast in the T field control was 43% on August 21 (Fig. 5B), similar to that observed in the G1 filed control. It increased to 70% on September 7. Although the incidence of panicle blast in zone 6 (out of wind range) in block C of the T field was low (20%) on August 21, it increased up to 57% in September 7. In contrast, the incidence of panicle blast was significantly lower in the other zones, especially in zones 2 and 3, where the incidence was 10% and 9%, respectively (Fig. 5B). The incidence in the other zones also remained below 25%.

The severity of panicle blast disease in the Control field was 8, 20 and 29 on August 21 and 29 and September 7, respectively (Fig. 5C). Similarly, the panicle blast severity values in zone 6 of block C in the T field were 6.5, 12.5 and 27 in August 21 and 29 and September 7, respectively. In contrast, the severity of the disease remained lower than 12 in all other zones. Zones 2 and 3 had the lowest severity values, which were 4 and 5, respectively.

T field received direct sunlight and exhibited a lower incidence and severity of leaf and panicle blast disease than the Control field. Fan-forced wind effectively reduced blast disease in zone 5, which received the lowest wind velocity (2.6–3.0 m/s), the same as observed in the G1 field.

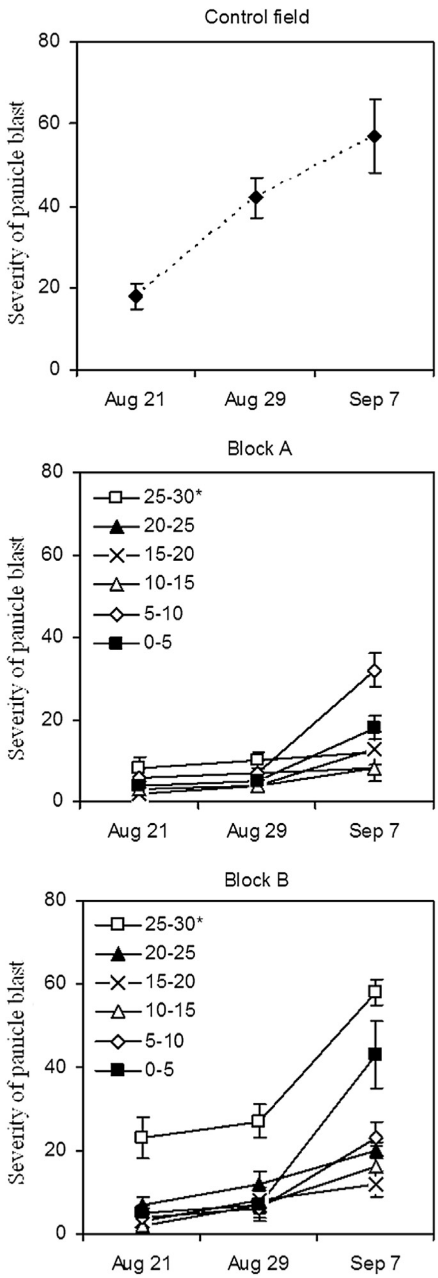


**Fig. 4.** Severity of rice panicle blast disease in Control field, block A and block B, respectively, in G1 field. *Distance (m) from the fan. Bars represent the standard errors.

### 3.2. Season 2

Leaf blast was not observed in any of the 14 blocks of the G2 field (Table 2) on July 9 and 14 and August 2 and 11. In contrast, the incidence of rice leaf blast was 0.75% in Control fields 1 and 2, which ranged from 3.0 to 14.7% from July 14 through August 11, respectively (Table 2).

After the formation of panicles, the incidence of chuff blast ranged from 1 to 8% in all G2 blocks except for blocks 4 and 7 (Table 2) on September 11 and 22. Rachis-branch blast was found only in block 2 at the rate of 1%. On September 30 (harvest day), rachis-branch blast was observed in all blocks at rates of 1–10%, while neck blast was observed at rates of 0–13%. The average incidences of panicle blast in G2 were 3.2 and 7.7% on September 11 and 30, respectively. However, chuff blast and rachis-branch blast ranged from 19 to 50% and 0 to 4%, respectively, in Control field 1 on September 11. On September 30, the incidence of rachis-branch blast and neck blast ranged from 6 to 22% and 13 to 67%, respectively. Furthermore, the incidence of chuff blast and rachis-branch blast in Control field 2 ranged from 21 to 35% and 3 to 18%, respectively, on September 11; however, rachis-branch blast and neck blast ranged from 17 to 23% and 32 to 66%, respectively, on September 30. The average disease incidences of panicle blast in the Control fields on September 11 and 30 were 35–39.7% and 52.3–70.6%, respectively.

## 4. Discussion

Rice blast fungus tends to become active when the humidity is 90% or higher (Leach, 1980; Merdith, 1973). This activity level reaches a peak from midnight to 2:00 AM (Barksdale and Asai, 1961; Kim et al., 1975; Leach, 1980). Airborne fungal spores between 6:00 PM and midnight are thought to be more responsible for blast infection (Iwano, 1984) because rice leaf blade surfaces remain moist for more hours during that period (Hashimoto et al., 1984). If the blade dries within 3–6 h after wetting, blast fungus cannot penetrate into the blade, resulting in a significantly reduced number of spots on the blades (Hashimoto et al., 1984). In this study, a fan-forced wind was generated between 11:00 PM and 4:00 AM to prevent leaf surfaces from remaining moist longer than 8 h, which is a sufficient time for blast fungus infection (Hashimoto et al., 1984; Yoshino, 1979). By using fan-forced wind, the period of wetness could be reduced to 5 h or less, which in turn, would prevent the penetration of blast pathogen into the plant tissues. Based on this assumption, artificially generated wind was delivered to rice plants with a large electric fan. Reductions in the incidence and severity of leaf and panicle blasts were obtained in the zones with wind velocities of 2.6–7.3 m/s for 60 s intervals. The effect of the wind at 2.0–2.6 m/s was inadequate, but it decreased the incidence of leaf blast compared to the non treated control fields.

The first and the second upper leaf blades of a plant are more vulnerable to infection by the blast fungus than others (Goto et al., 1961; Kato and Diamond, 1966; Yoshino, 1979). It is possible to reduce the disease incidence by blowing or drying water drops off blades or panicles at the tops of plants. In this study, serious outbreaks of rice blast were obviously prevented by applying artificially generated wind at an appropriate velocity to the paddy fields. The mechanism of moisture loss on leaf blades or panicles when wind was generated at 11:00 PM and 4:00 AM was not elucidated, especially in relation to the various growth stages of plants.

Water drops on leaf blades gradually disappear as the sun rises, with those on the upright blades or panicles at the top of the plant usually disappearing first (Hashimoto et al., 1984). Blades are more severely affected by blast in cloudy weather because they dry more slowly (Hashimoto et al., 1984). In our experiments, the outbreak of rice blast was greatly reduced by very effective application of wind to the paddy fields that were exposed to sunlight at sunrise. However, the suppression effect was inadequate in the field where the grove blocked the sunlight at sunrise, possibly by the water droplets remaining longer on the plants. Therefore, to determine the period and frequency of wind application, it is necessary to clarify the time required for the water droplets to evaporate or dislodge from the surface of plants as well as the influence of water drops recondensing on the surface after the blowing operation.

High-velocity wind could injure the rice blades or panicles and predispose them to damage from the blast fungus (Hirano and Gotou, 1963; Sakamoto, 1940; Shimada, 1937). A velocity of 9 m/s has been reported to result in severe infection with rachis-branch blast, while 12 m/s resulted in even greater severity (Hirano and Gotou, 1963). In our experiments, rice plants planted near the fan

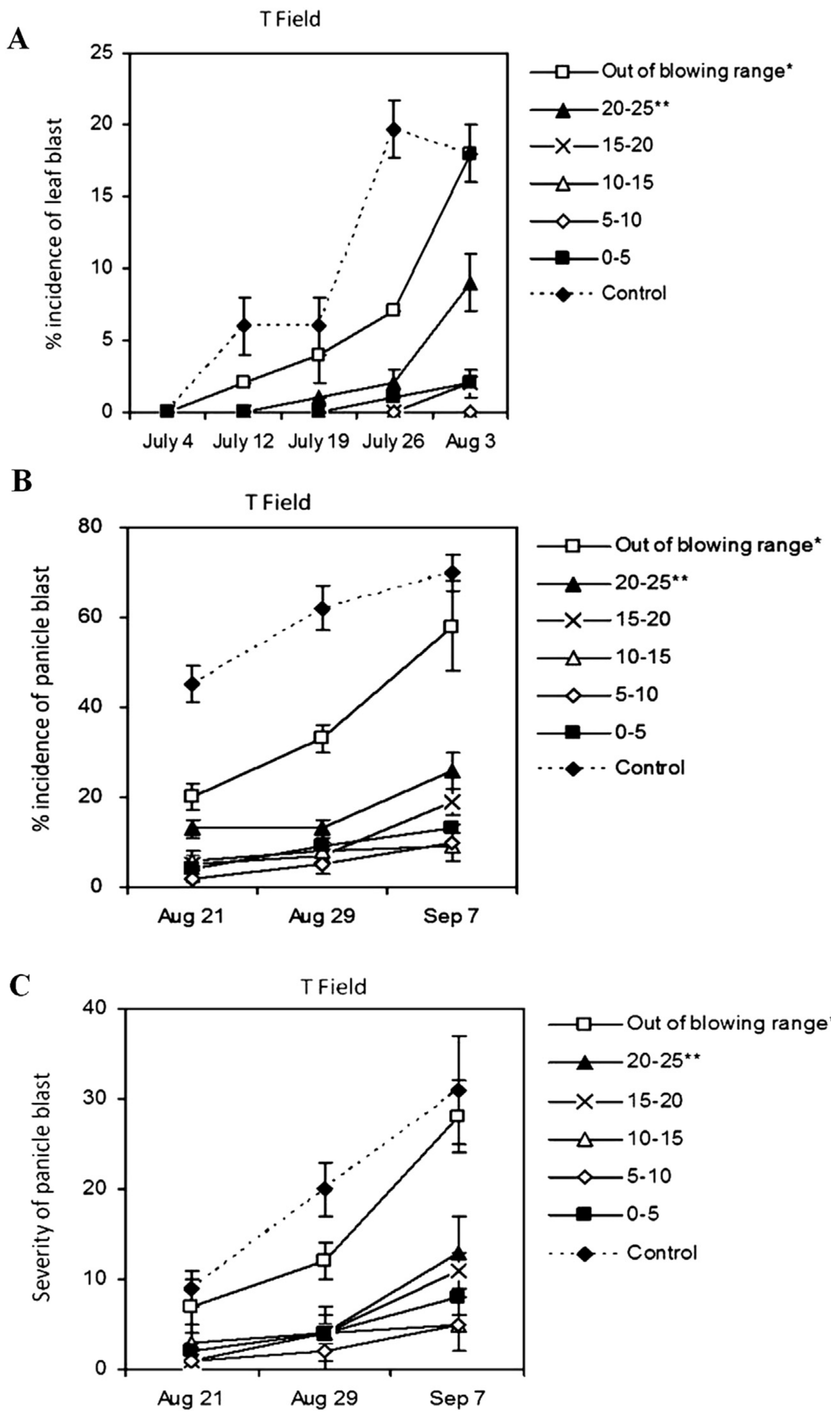


**Fig. 5.** Incidence of rice leaf (A) and panicle (B) blast diseases and severity of rice panicle blast disease (C) in T field; *indicated in Fig. 1. **Distance (m) from the fan. Bars represent standard errors.

were exposed to a velocity >7.3 m/s every day and sustained damage to the leaves; they were consequently affected by severe node blast or panicle blast. In contrast, leaf and rice blast were significantly suppressed in plants receiving an adjusted velocity of ca. 3–6 m/s in the G2 field. Therefore, it is necessary to maintain a maximum wind velocity of 6 m/s or lower.

Although the occurrence of rice blast was reduced in zones 2, 3 and 4 (velocity >3 m/s), leaf blast increased in the zones 5 and 6 (2.0–3.0 m/s) in the G1 and T fields in early August immediately before the formation of panicles. In such zones, increases in panicle blast were evident in September 7 immediately preceding the harvest. It has been reported that rice plants a later stage after the formation of panicles tend to be easily infected with panicle blast, resulting in a serious outbreak (Hirano and Gotou, 1963; Katsube and Koshimizu, 1970). It is necessary to adjust wind velocity to between 3 and 6 m/s to obtain sufficient blast disease control. Another factor that might be responsible for the increase of the disease in zones 5 and 6, especially before harvesting, is the rapid growth of stems and leaves in mature plants, which might have impeded the airflow, and provided an environment suitable for blast. The stems might also be become harder, causing the plants to swing less and facilitating the infection of panicles as a result of fewer water drops being blown off. These potential factors suggest that it is necessary to study the fan-forced wind method in relation to plant density, the number of roots in a single planted hill, and planting directions. As agricultural chemicals had been applied to Control field 1 throughout the experiment, the above data clearly showed that wind treatment was more effective than the application of chemical fungicides in controlling the outbreak of leaf blast. Additionally, rice production was not negatively affected by wind treatment.

Further work is needed to determine the mechanisms involved in the phenomenon of potential rice blast disease reduction by wind including the effect of wind on spore load in the atmosphere above the crop and the potential for the wind to dislodge spores of the blast fungus or to deter insect pests.

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