

Full Length Research Paper

Effect of artificially-generated wind on removing guttation and dew droplets from rice leaf surface for controlling rice blast disease

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The incidence and severity of leaf and panicle blasts were efficiently reduced in the wind-treated fields. Artificially-generated wind was performed on rice paddy field in order to measure the changes in temperature and humidity during and after the blowing process and to investigate the effects of sending wind on the formation and removal of guttation and dew droplets on rice leaves. A large electric fan was used to send wind with a depression angle of 30° at 4:00 AM for 30-40 min. During the blowing process, the humidity percentage was 100% in both treated and control paddy fields, the temperature was 0.8°C higher in the treated than the control field and the dew weight was rapidly decreased from 21 to 8 g in 20 min in the treated field. After the blowing process, the temperature started to rise at 6:28 AM (10 min earlier than the control block). It reached 29°C at 6:48 AM (30 min earlier than the control block) and remained higher than the control block till 7:20 AM (1-7°C higher). The humidity decreased to 95% at 6:30 AM (20 min earlier than the control block) and remained 95% till 6:42 AM, then rapidly decreased to reach 68% at 6:46 AM, and finally reached 60% at 7:20 AM. The humidity was 5-30% lower than that in the control block. Moreover, the dew weight increased to the initial level within 10 min and then decreased rapidly in both blocks starting from 6:20 AM. Using wind speed of 4.3 m/s or 3.2 m/s for 60 s per rotation at 4:00 AM, almost all the guttation droplets except those of less than 0.5 mm were removed from the surfaces of the 1st and 2nd uppermost leaves after two rotations (at velocity 4.3 m/s) or three rotations (at velocity 3.2 m/s) and the dew droplets were mostly removed after five rotations (at velocity 4.3 m/s) or nine rotations (at velocity 3.2 m/s). Sending wind at a speed of 3.2 m/s or faster removed guttation and dew droplets and suppressed the subsequent dew formation. Our data indicates that the removal of dew droplets on rice hills resulted in reduction of the disease development of *Pyricularia oryzae*.

Key words: Generated-wind, rice blast, microclimate, guttation, dew droplets.

INTRODUCTION

Rice blast disease, caused by *Pyricularia oryzae*, is one of the major causes of reduction of rice production in the

world. The severity of rice blast disease is strongly influenced by the prevailing weather conditions that rain,

wind, temperature and sunlight. Wind is thought to reduce the number of spores attached to rice plant and to promote removal of dew droplets on the leaves. Thus, the penetration of blast into leaves might be prevented or impeded (Adachi, 1981; Hashimoto et al., 1984; Misawa and Matsuyama, 1960; Mousanejad et al., 2009; Ono and Suzuki, 1959; Suzuki, 1969). Taguchi et al. (2014) reported that outbreaks of rice blast were remarkably prevented by sending artificial wind to the paddy fields. In their 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 sufficient time for blast fungus infection (Hashimoto et al., 1984; Yoshino, 1979). They also reported that it is necessary to adjust wind velocity to between 3 and 6 m/s to obtain sufficient blast disease control.

It is generally presumed that artificial blowing has preventive effects on rice blast because blowing causes changes in the microclimate over paddy fields, including increased temperature and reduced humidity, promoting removal of guttation/dew droplets formed on rice leaves, or wind compulsorily blows off blast spores attached to rice plants (Adachi, 1981). However, no detailed explanations have been given to how wind changes the microclimate over the paddy field and how guttation/dew droplets disappear from the leaf surface. In the present work, we studied how artificially-generated blowing influences temperature and humidity on paddy field and how it promotes the disappearance of water droplets on the uppermost rice leaves.

MATERIALS AND METHODS

Effect of artificially-generated wind on dew formation on the surface of rice leaves

The experiment was conducted in a mountainous area of Gifu prefecture suffering from serious outbreaks of rice blast for several years. Rice seedlings of "Kinuhikari" cultivar with three leaves (3 weeks after sowing) were used for transplanting. A paddy field (60 m x 30 m) was planted with rice seedlings (30 cm line interval, 18 cm hill interval and 20 plants / m²). A large electric fan with a rotation angle of 180° (5 KW, blade diameter of 110 cm, wind volume of 4,020 m³/min) was installed at the ridge of the paddy field (1 m away from the edge of the ridge). The fan was set on the top of 5 m pillar with a depression angle of 30°. By using this fan, rotating wind was sent to rice hills for 30 min starting from July 23 at 4:00 AM (each rotation lasts for 60s with 2 min interval). Sending wind was started from 6 weeks old rice seedlings (3 weeks after transplanting). A dew meter (Hokutow E-T11A, Japan) was installed 60 cm high from the ground level at a particular point in the paddy field where the wind speed was 3.5 m/s to study changes of the guttation/dew formation levels both during and after the blowing operation (Hashimoto et al., 1984). Additionally, the guttation/dew formation status of the control block, adjacent to the west side of the designated block, was studied.

Effect of artificially-generated wind on the temperature and humidity on paddy field

Wind was sent to the paddy field on July 19 and August 10 as described previously. A thermometer and a hygrometer were installed at a particular point where the wind speed was 3.5 m/s (80 cm high from the ground level) to measure changes in temperature and humidity on the paddy during the blowing operation and also during the subsequent time zone between 6:20 and 7:00 AM. The blowing operation lasted for 30 min starting at 4:05 AM on July 19, and for 40 min from 3:50 to 4:30 AM on August 10.

Effect of artificially-generated wind on disappearance of guttation/dew droplets from the leaf surface

For evaluation of guttation/dew droplets formation on rice leaves, the total number and location of guttation droplets of 0.2 mm or larger were recorded. Additionally, the presence or absence of microscopic dew droplets was also recorded. Guttation droplets were classified according to their size to; larger than 1.5 mm, 1.0-1.5 mm, 0.5-1.0 mm and 0.2 - 0.5 mm. The number in each class was recorded. Since, it was difficult to count the number of dew droplets, they were evaluated collectively according to coverage area of rice leaves to: "++++" for full covering leaf surface area with dew droplets, "+++" for 2/3 of the leaf surface area covered with dew droplets, "++" for 1/3 of the leaf covered with dew droplets, "+" for 1/3 or less of the leaf covered with dew droplets, and "-" for no dew droplets. For the control block, a particular position was selected in the identical paddy field to record the same measurements. The formation of guttation and dew droplets was measured at 3:50 am and at 4:50 am.

By using a large electric fan, rotating wind was sent to the paddy field for 30 min starting at 4:00 AM on July 19. Three rice hills in the zone where the wind speed was 4.3 m/s and other 2 rice hills in the zone where the wind speed was 3.2 m/s were selected to measure guttation/dew droplets formation on the unfolded first and second uppermost leaves. The measurements were performed 10 min before and after blowing process, as well as during the process. During the blowing process, the measurements were performed during the intervals of the rotation cycles. The measurements were performed 9 times (once per rotation cycle) and 5 times (every 2 rotation cycles) in the zone of wind speed 4.3 and 3.2 m/s, respectively.

RESULTS

Effect of artificially –generated wind on the dew droplets formation on the rice leaf surface

The values of the guttation/dew droplets were same in the treated and control fields just before starting the blowing operation. During the blowing process, the dew weight rapidly decreased from 21 to 8 g in 20 min. After the blowing process, the values of the dew droplets weight in the treated block were 2 g lower than the values in the control block. The weight values in both blocks decreased rapidly starting from 6:20 AM. The values of the dew droplets in the treated and control blocks were

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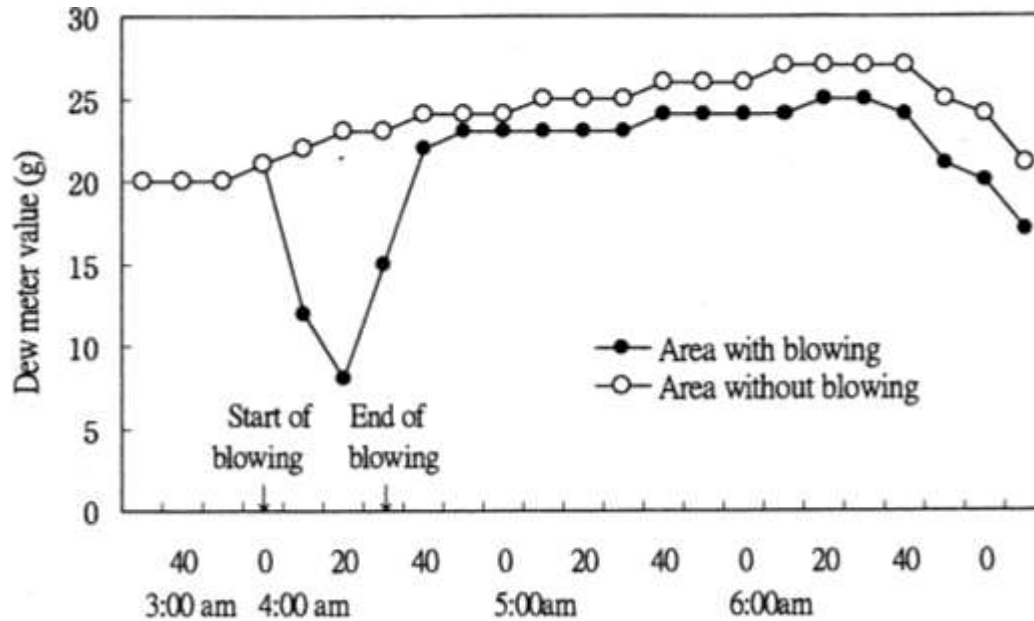


Figure 1. Dew droplets weight on the rice leaf surface in the treated and control blocks.

illustrated (Figure 1).

Effect of artificially-generated wind on the temperature and humidity on paddy field

Early during blowing process

On July 19, the temperature was 17.2°C at 4:05 AM then increased to 17.7°C and remained at this level during the blowing process for 30 min. In the control block, the temperature was about 0.8°C lower than those in the treated block (Figure 2A). On August 10, the temperature was 19.5°C at 3:50 AM and remained almost at the same level for 40 min during the blowing process (Figure 2B). The temperature was slightly decreased after the blowing process. On the other hand, the temperature in the control block gradually decreased and was 0.9°C lower than treated block at 4:30 AM. The humidity levels in both blocks remained at the level of 100% on both July 19 and August 10 with regardless of blowing process (Figure 2A and 2B).

Later after blowing process from 6:20 to 7:20 AM

On July 19, the temperature and humidity from 6:20 to 7:20 AM were recorded in both treated and control blocks. The temperature in the control block increased gradually from 6:38 AM and reached 30°C at 7:20 AM (Figure 3A). In the treated block, the temperature started to increase at 6:28 AM (10 min earlier than the control block), and reached 29°C at 6:48 AM (30 min earlier than the control

block). The temperature remained higher than the control block till 7:10 AM (1-7°C) (Figure 3A). In control block, the humidity percentage decreased gradually from 6:52 AM and reached 60% at 7:20 AM (Figure 3B). In the treated block, the humidity decreased to 95% at 6:30 AM (20 min earlier than the control block) and remained 95% till 6:42 AM, then rapidly decreased to reach 68% at 6:46 AM, which maintained for a while, and finally reached 60% at 7:20 AM. The humidity percentages in the treated block were lower than that in the control block (ranged 5-30%) (Figure 3B).

Although, an increase in temperature and decrease in humidity percentage were also observed in the treated block compared with the control after the blowing process on August 10, both temperature increased and humidity reduction started later after those occurred on July 19 (Figure 4). They tended to be similar changes and were consistently observed on both dates.

Artificially-generated wind effectively promoted the removal of guttation/dew droplets on the leaf surface

On July 19, the disappearance of guttation/dew droplets which formed on the first and second uppermost rice leaves was measured when the wind speed was 4.3 and 3.2 m/s in the treated block.

Using wind speed of 4.3 m/s

Just before blowing, 7 (larger than 1.5 mm in diameter), 22 (ranged from 1.0 to 1.5 mm) and many (of 0.5-1.0

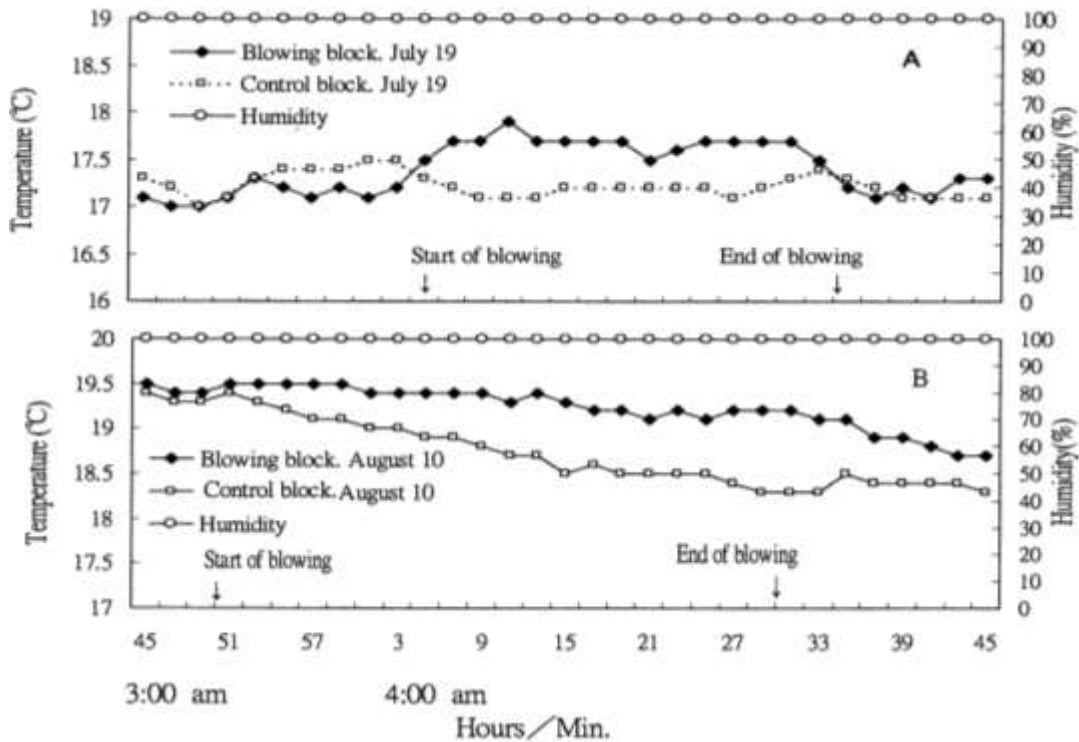


Figure 2. Temperature and humidity values in both treated and control blocks during the blowing process on July 19 (A) and August 10 (B).

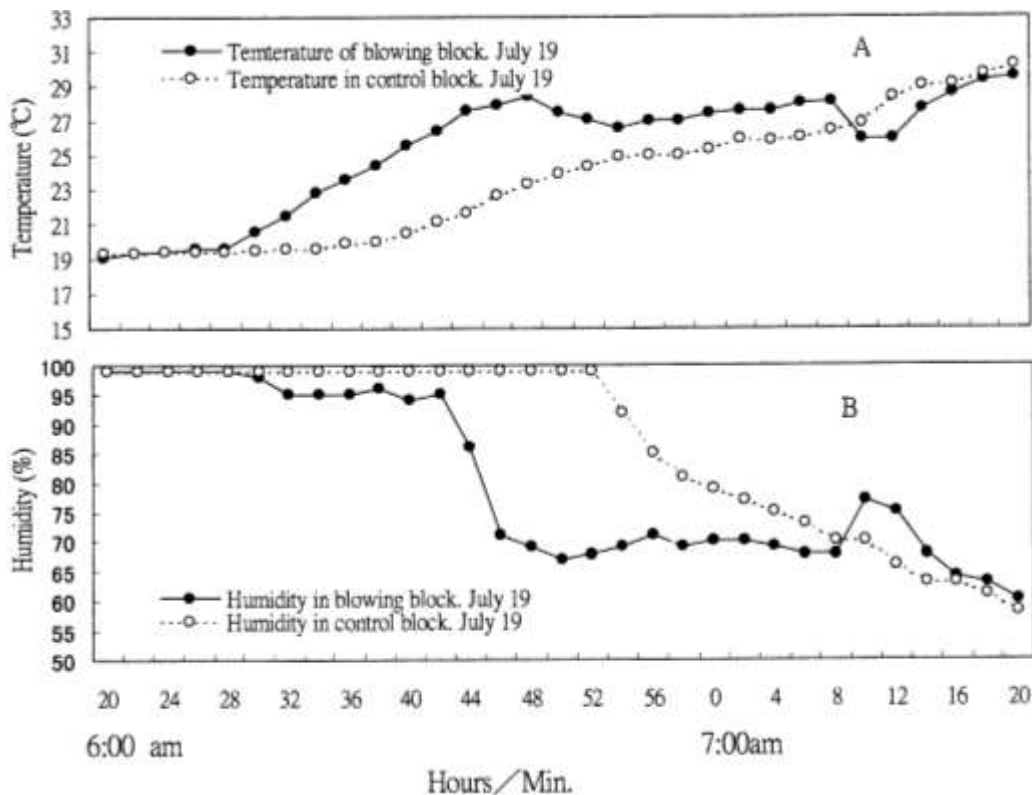


Figure 3. Temperature (A) and humidity (B) values in both treated and control blocks after the blowing process on July 19.

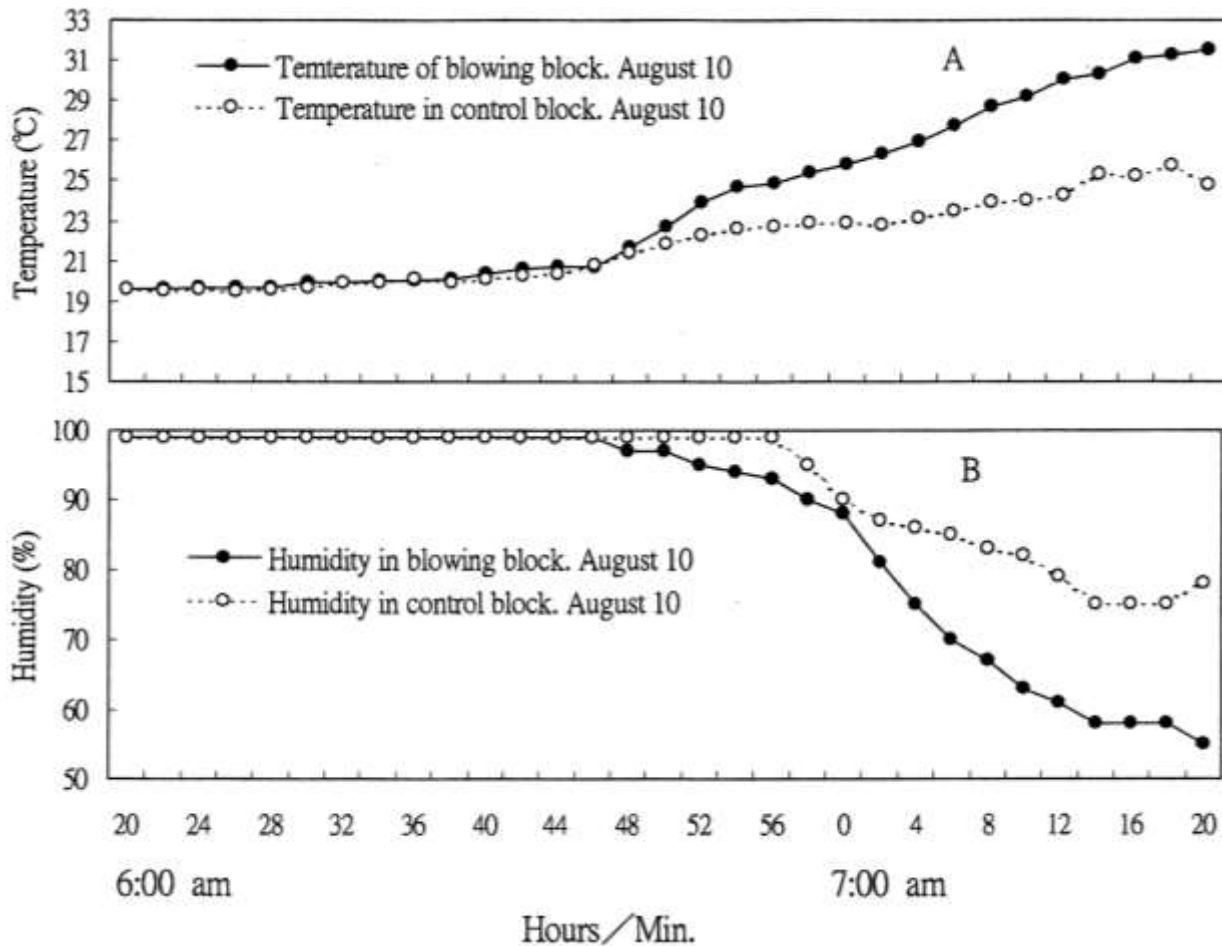


Figure 4. Temperature (A) and humidity (B) values in both treated and control blocks after the blowing process on August 10.

and 0.2 -0.5 mm in diameters) guttation droplets were observed on the first uppermost leaves as well as microscopic dew droplets that covered the entire leaf surface giving it white color. The first rotation of fan at wind speed of 4.3 m/s removed 1.5 mm or larger guttation droplets and those of 0.5-1.0 mm, leaving a small number of 1.0 -1.5 mm-sized droplets and many of those of 0.2-0.5 mm in diameter on leaf surfaces, as well as the majority of the dew droplets. The second rotation removed all guttation droplets of 0.5 mm or larger, but 12.3 of 0.2-0.5 mm-sized droplets were accumulated on the leaf edges immediately after ending of the second rotation. The dew droplets were reduced to 2/3 or less of the entire leaf surface. After the third rotation, the removal of re-accumulated guttation droplets and reduction of dew droplets were gradually succeeded. The process repeated due to consequently re-accumulation of guttation droplets on leaf edges again but no remarkable reduction was observed after the seventh rotation. Ten min after stopping the blowing, re-formed guttation droplets grew larger (1.3 droplets of 1.5 mm or larger,

15.0 droplets of 1.0 -1.5 mm). Many of re-formed guttation droplets appeared at the same locations on the leaf surface as those observed before the blowing process. However, most of the dew droplets were removed. The distribution of guttation and dew droplets before and after fan rotations is illustrated in Table 1.

Just before blowing, 7.0 (larger than 1.5 mm), 18.5 (ranged from 1.0 mm to 1.5 mm) and many guttation droplets (0.5-1.0 and 0.2-0.5 mm) as well as microscopic dew droplets covered the entire surfaces of the second uppermost leaves. The first fan rotation at wind speed of 4.3 m/s removed the majority of guttation droplets (1.5 mm or larger) and those of 1.0 -1.5 mm. However, the majority of the guttation droplets of 0.5 -1.0 mm as well as those of 0.2-0.5 mm remained on the leaf surface. Moreover, most of the dew droplets remained unremoved. The second rotation removed all of the guttation droplets of 0.5 mm or larger. But 11.0 guttation droplets of 0.2 -0.5 mm were re-formed on the leaf and dew droplets covered over 2/3 of the leaf surface. After the third rotation, removal of the re-formed guttation and decrease of dew

Table 1. Relation between appearance /disappearance of guttation /dew on unfolded uppermost leaves ^a of rice hill and blowing wind at velocity of 4.3 m/s.

Leaf position	Guttation/dew droplet diameter and classes	Number of droplets before blowing (per leaf)	Number of blowing rotations ^b									10 min after blowing	
			1	2	3	4	5	6	7	8	9		
1 st uppermost leaf ^a	Over 1.5 mm	7.0	0	0	0	0	0	0	0	0	0	0	1.3
	1.0-1.5 mm	22.0	0.3	0	0	0	0	0	0	0	0	0	15.0
	0.5-1.0 mm	>30 ^c	0	0	0	0	0	0	0	0	0	0	0
	0.2-0.5 mm	>30 ^c	>30	12.3	9.3	16.0	9.3	17.3	15.3	5.3	5.3	0	0
	Dew droplet groups ^d	++++	+++	++	++	+	+	+	+	+	+	+	-
2 nd uppermost leaf ^a	Over 1.5 mm	7.0	0	0	0	0	0	0	0	0	0	0	2.0
	1.0-1.5 mm	18.5	0	0	0	0	0	0	0	0	0	0	16.0
	0.5-1.0 mm	>30 ^c	>30	0	0	0	0	0	0	0	0	0	0
	0.2-0.5 mm	>30 ^c	>30	11.0	3.0	3.5	8.0	17.0	19.5	9.5	0	0	0
	Dew droplet groups ^d	++++	++++	+++	+++	++	+	+	+	-	-	-	-

^aThe average leaf length of 1st uppermost leaves was 36.0 cm, and that of 2nd uppermost leaves was 38.5 cm. ^bThe number of exposure processes of rice hills to the rotation wind. The blowing time in a single rotation was 60s. ^cThe symbol ">30" means that over 30 guttation droplets were formed on a single leaf. ^dThe dew group means a colony of dew droplets. A different symbol is given to each group according to degree of the coverage over the leaf. They are "++++" for full coverage; "+++ for 2/3 coverage; "++" for 1/3 to 2/3 coverage; "+" for smaller than 1/3; and "-" for no coverage.

droplets were repeated. At the ninth rotation of blowing, no formation of guttation droplets was observed. Ten min after the blowing, the guttation droplets accumulated forming larger droplets. 2 droplets of 1.5 mm or larger and 16 of 1.0-1.5 mm were observed (Table 1).

Using wind speed of 3.2 m/s

Rice hills were examined 5 times (once every 2 rotations) using wind speed of 3.2 m/s for the disappearance of guttation/dew droplets. Just before blowing, 2.0 (of 1.5 mm or larger), 9.0 (of 1.0 -1.5 mm) and many of guttation droplets (of 0.5-1.0 mm and of 0.2-0.5 mm) were observed on the surfaces of the first uppermost leaves. After the first rotation using wind speed of 3.2 m/s, the number of guttation droplets of 1.5 or larger decreased to 0.5 and those of 0.5-1.0 mm decreased to 3.5; but the majority of the guttation droplets of 1.0-1.5 mm and those of 0.2-0.5 mm as well as most of the dew droplets remained on the leaf surface. After the third rotation, the remaining guttation droplets of 1.5 mm decreased to 0.5 and those of 0.5-1.5 mm were completely removed. Immediately after third rotation of blowing, 5.0 guttation droplets of 0.2-0.5 mm were re-formed on the leaf margins and the number of dew droplets decreased slightly. After the fifth rotation, removal of the re-formed guttation droplets and decrease of dew droplets were repeated. After the ninth rotation, a fewer dew droplets were observed. Ten minutes after the blowing, larger guttation droplets were re-formed (6.5 of 1.0-1.5 mm and

3.5 of 0.5-1.0 mm). A few dew droplets remained around the bottom of the leaves (Table 2).

Just before blowing, 7 (of 1.5 mm or larger), 18.5 (of 1.0 -1.5 mm) and many guttation droplets (0.5 -1.0 mm and 0.2-0.5 mm) as well as microscopic dew droplets covered the entire surface of the second uppermost leaves leaving them white in color. After the first rotation using wind speed of 3.2 m/s, all of the guttation droplets of 0.5 mm or larger were removed, but many of 0.2 -0.5 mm were remained on the leaf surface. Similarly, the majority of the dew droplets covered most of the leaf surface. After the third rotation, all guttation droplets of 0.5 mm or larger were removed, but 11 guttation droplets of 0.2-0.5 mm were re-formed on the margins of the leaf surface. Dew droplets covered almost 2/3 of the leaf surface. After the fifth rotation onward, removal of the re-formed guttation droplets and decrease of dew droplets were repeated. After the ninth rotation, dew droplets were reduced to 1/3 or less of the leaf surface. Ten minutes later after stopping the fan, larger guttation droplets were observed (8.5 guttation droplets of 1.0-1.5 mm and 2.5 guttation droplets of 0.5-1.0 mm) on leaf surface. Few dew droplets were observed on the bottom of second upper most leaves (Table 2).

DISCUSSION

Rice blast severity is affected by weather factors such as daily relative humidity and temperature, amount of precipitation and dew, speed direction of wind and condi-

Table 2. Relation between appearance/disappearance of guttation/dew on unfolded uppermost leaves ^a of rice hill and blowing wind at velocity of 3.2m/s.

Leaf position	Guttation/dew droplet diameter and classes	Number of droplets before blowing (per leaf)	Number of blowing rotations ^b					10 min after blowing
			1	3	5	7	9	
1 st uppermost leaf ^a	Over 1.5 mm	2.0	0.5	0.5	0	0	0	0
	1.0-1.5 mm	9.0	3.5	0	0	0	0	6.5
	0.5-1.0 mm	>30 ^c	>30	0	0	0	0	3.5
	0.2-0.5 mm	>30 ^c	>30	0.5	3.5	0.5	5.5	0
	Dew droplet groups ^d	++++	+++	+++	+++	++	+	+
2 nd uppermost leaf ^a	Over 1.5 mm	7.0	0	0	0	0	0	0
	1.0-1.5 mm	18.5	0	0	0	0	0	8.5
	0.5-1.0 mm	>30 ^c	>30	0	0	0	0	2.5
	0.2-0.5 mm	>30 ^c	>30	11.0	3.0	3.5	8.0	0
	Dew droplet groups ^d	++++	++++	+++	+++	++	+	+

^aThe average leaf length of 1st uppermost leaves was 37.0 cm, and that of 2nd uppermost leaves was 31.5 cm. ^bThe number of exposure processes of rice hills to the rotation wind. ^cThe symbol ">30" means that over 30 guttation droplets were formed on a single leaf. ^dThe dew group means are a colony of dew droplets. A different symbol is given to each group according to degree of the coverage over the leaf. They are "++++" for full coverage; "+++"; for 2/3 coverage; "++" for 1/3 to 2/3 coverage; "+" for smaller than 1/3; and "-" for no coverage.

tion of sunshine (Adachi, 1981; Leach, 1980; Taguchi et al., 2014). Water droplets on the leaf surface are one of the important factors that are implicated in outbreaks of many fungal diseases (Burrage, 1971; El Refaei, 1977; Long, 1955; Long, 1958; Monteith and Butler, 1979; Wallin, 1963). The dew formation on the leaf surface is one of the main factors which are responsible for outbreak of rice blast (Burrage, 1971; Long, 1955; Long, 1958; Monteith and Butler, 1979; Wallin, 1963). Persistence of guttation/dew droplets for a while on the leaf surface is a requisite for contagions with rice blast (Hashimoto et al., 1984; Hemmi and Abe, 1931; Kim et al., 1975; Yoshino, 1979). In our previous study (Taguchi et al., 2014), outbreaks of rice blast (both leaf and panicle blasts) were remarkably prevented by sending artificial wind which was generated 2 times daily for 30 min each starting at 11:00 PM and 4:00 AM, respectively, to the paddy fields to prevent leaf surfaces from remaining moist longer than 8 h, which is sufficient time for blast fungus infection (Hashimoto et al., 1984; Yoshino, 1979). Our results also show that it is necessary to adjust wind velocity to between 3 and 6 m/s to obtain sufficient blast disease control. Such wind treatment was more effective than the application of chemical fungicides in controlling the outbreaks of leaf and panicle blast.

The present study investigated the influence of artificially-generated wind on removal of dew/guttation droplets from rice leaf surface based on visual observation and measurement of transitional values by dew meters and how that would effectively prevent or interfere with rice blast infection (Hashimoto et al., 1984). The correlation between guttation/dew formation and weather conditions in the natural environment have been previously reported (Arai, 1951; Crowe et al., 1978; Hsu

et al., 1980; Lloyd, 1961; Lomas, 1965; Newton and Riley, 1964; Picking and Jiusto, 1978). Likely, the formation of guttation droplets is gradually increased on the tip or margins of the leaf surface until 2:00 or 3:00 AM (Barksdale and Asai, 1961). In the present study, if the wind is artificially sent at a speed of 3.2 m/s at 4:00 AM, guttation droplets on the uppermost leaves are easily dropped off after 2 or 3 rotations of fan. The small guttation droplets were re-formed again on the leaf margins during the rotation intervals. These facts suggested that such artificially-blown wind may greatly contribute to the removal of the guttation droplets.

Dew droplets form as a water film with a high surface tension on leaf surface (Beysens, 1995), which is suitable for the germination of various species of fungi (Suzuki, 1973; Wallin, 1967). In windless days, formation of dew droplets reaches the peak level between about 4:00 and 6:00 AM (Barksdale and Asai, 1961; Hashimoto et al., 1984). If the wind velocity goes beyond a particular level in the natural environment, further dew formation is prevented and the formed dew evaporates (Hashimoto et al., 1984; Hsu et al., 1980; Suzuki, 1969). In the present experiment, several rotations of artificial-generated wind at speed of 3.2 m/s or 4.3 m/s removed most of the dew droplets on the leaves, but the dew droplets re-formed again after stopping the fan. Thus, the artificial blown wind can remove the formed dew droplets on leaves, but it cannot prevent their formation because dew formation is a dynamic process in the natural environment. The humidity on the paddy was 100% in both control and treated blocks and the temperature was 0.8°C higher in the treated block than the control. Therefore, it can be presumed that the disappearance of dew/guttation droplets was due to physical removal by the artificially-

generated wind.

The disappearance time of dew begins by drying the dew rapidly to the degree that 10 g or greater volume of dew disappears in 3 h, on the condition that the weight of dew in filter paper (29 × 80 cm) increased once and was then maintained for 3 h (Hashimoto et al., 1984). They also considered that when there is a rapid decrease in dew weight due to an intermission of rainfall, etc., the dew can be regarded as being continuously maintained if there is further rainfall within 3 h. The disappearance of dew on the leaf surface due to artificial wind can be considered as an intermission of dew formation because the disappearance occurs momentary - few minutes. Furthermore, the amount of dew formed after stopping the fan is smaller than those observed in the control block. Therefore, the increase in temperature and reduction in humidity were effectively promoted after sunshine (sunrise) on the paddy field and the drying process of the rice hills gradually progressed.

Sending wind to rice nurseries for consecutive 12 h from the evening to the following morning for 15 days prevented the formation of guttation/dew droplets on the leaf surface as well as germination and penetration of conidiospores, resulting in suppression of outbreak of leaf blast (Adachi, 1981). In addition to the disappearance of guttation/dew droplets in early morning, humidity reduction and rapid increase of temperature early during sunrise could also be considered as the factors that prevent or interfere with penetration of blast fungi.

Artificially-generated wind at speed of 3.2 m/s or 4.3 m/s effectively removed the guttation/dew droplets formed on leaves. The infection rate with rice blast is correlated with the exposure time to guttation/dew droplets, thus removal of guttation/dew droplets by blowing can surely suppresses infection of blast fungi.

It can also be considered that artificial-generated wind is related to disappearance of guttation/dew droplets. Fan-generated wind speed of 3.2 m/s or 4.3 m/s at angle of 30° with a total of 9 rotations (1 min each and 2 min intervals) resulted in removing the majority of the guttation/dew droplets although a slight amount of dew remained at the bottom of leaves. On the other hand, although the guttation droplets disappeared in 20 s when wind at a speed of 3 m/s was blown in a single direction, dew droplets could not be removed even when the wind was blown continuously for 25 min (data not shown). These facts suggest that it is effective to intermittently generate wind by a large electric fan from a higher position. It can be presumed that this is because such wind can blow into the rice hills, shaking the entire rice hills. Also, rotating wind can produce frequent changes in wind speed, shaking leaves irregularly; causing the leaves to touch each other's resulting in the promoted disappearance of the guttation droplets as well as the re-formation of guttation droplets from the leaf surface. Additionally, when guttation droplets scatter, they contact the water film of dew on the leaf surface, resulting in

promoted disappearance of dew. Hashimoto et al. (1984) suggested that dew flow on the leaf surface was partly contributed to washing conidiophores off of leaf surface. Although wind at velocity of 2 m/s could hardly blow spores off the lesions, wind at velocity of 4 and 5 m/s could remove them more effectively (Misawa and Matsuyama, 1960; Suzuki, 1969). This effect became more obvious in high humid conditions (Barksdale and Asai, 1961; Leach, 1980; Ono and Suzuki, 1959). These facts suggest that artificial sending wind influences the formation of conidiospores attached to the leaf surface. Thus, further study is necessary to investigate how artificial wind can influence germination of conidiospores as well as formation of appressoria and how blast fungus spores could be washed down by the flow of dew (Schrodter, 1960; Suzuki, 1973). Effect of weather on spore germination of rice blast has been studied by Mousanejad et al. (2009). They showed that the spore germination of rice blast was increased when relative humidity was increased and maximum temperature and sunny hours were decreased.

Conflict of interests

The authors did not declare any conflict of interest.

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