Behavior of Rice Blast Fungus Spore and Application to Outbreak Forecast of Rice Blast Disease

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The establishment of a practical forecasting method with high accuracy for the blast disease of rice has been sought because this is one of the most injurious diseases of rice plant.

The forecasting by spore trapping, in any trapping method applied, must be based on the precise behavior of spore from the release stage to the invasion into plant, especially from the viewpoint of climate. From such standpoint, study was carried out to establish a forecasting method of blast disease occurrence in consideration of the diffusion of spore and the number of invasive spores. The outline of the study shall be described hereunder.

Trial fabrication of a whirling sampler and its utilization for forecasting

The method of spore trapping can be roughly divided into two types; one is the gravity sedimentation method and the other is the inertial method. Though both of them possess merits and demerits, the whirling sampler

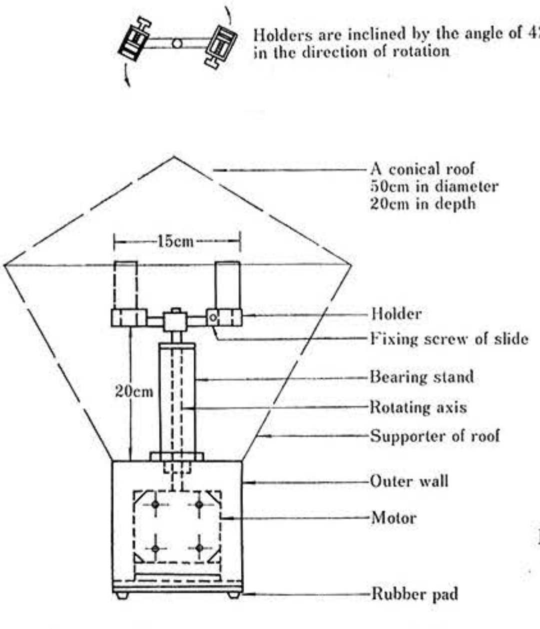

Fig. 1. Outlined scheme of the whirling sampler

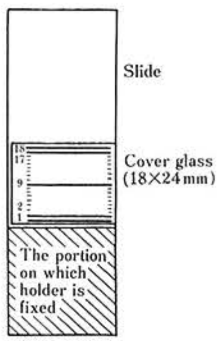

Fig. 2. The position of slide detected with a microscope. The figures in the cover glass are the rows in the field of vision

was made with the structure shown in Fig. 1 because the latter is better for the trapping of spores of this fungus.

The main structure of this sampler consists of a rotating axis of which the upper end is attached with two slide glass holders, and this axis can be rotated by an electric motor.

Owing to the rotation of the axis, the surface of the slide glass receives the wind force which corresponds to that received by the slide glass which was erected perpendicularly in the air current of 9.8 m/sec., therefore, it is possible to estimate the amount of air current received by the slide glass.

The performance time of this device is from 1 a.m. to 2 a.m., and the surface of the slide glass supported on the holder is covered with a thin layer of glycerin-jelly.

The number of the spores trapped on the slide glass is counted at the position, as in Fig. 2, covered with a cover glass (18×24 mm) being detected with a microscope of 150 magnifications. But in the case when the time to spare for the detection is wanted or too many spores are trapped to be counted, only the spores detected on the second line (from the lower end), the ninth line (middle line) and the 17th line (the second line from the upper end) in the cover glass area shown in Fig. 2 are counted, and from this result, the whole number of the spore in the area of 18×24 mm may be obtained by conversion.

The sampler can be set in any paddy field under the standard cultivation practice of the region, and the adequate position to set the sampler in the spore trapping paddy field of 5a may be at the center of the field with a height of 1.3 m above the ground. This sampler may also be available to trap a fairly good amount of spores on the roof of a building of about 10 m height when this building is surrounded by paddy fields.

The relation between the number of spores trapped at the positions of both heights described above and the occurrence of leaf blast and panicle blast was examined with the following results:

Compensation of the number of trapped spores by wind velocity and the number of rainy days

In the forecasting of disease occurrence by means of the number of trapped spores in the

1) Trapping of spores at the height of 1.3 m above the paddy field

The first date of successive trapping of spores	Average collected spore number for five days until 15th of July	Expected degree of blast outbreak	
		Leaf blast	Panicle blast
After the second half decade of July	less than 30	less than $II_{0.5}$	less than 5%
After the first half decade of July	30～100	$III_2 \sim IV_{11}$	20%
After the fifth half decade of June	100～500	IV_{11}	60%
After the second half decade of June	more than 500	more than V_{55}	100%

2) Trapping of spores at higher position (8–17 m)

Trapping condition of spore	Disease occurrence of leaf blast	Diseased panicle rate of panicle blast
Spores were trapped discontinuously until the second half decade of July, and also after the third half decade, only one or two spores were trapped	$II_{0.5}$	10%
Spores were trapped continuously after the second half decade of July, and also after the third half decade, more than ten spores were trapped	$III_5 \sim V_{25}$	30%

Note: The standard of disease rate of leaf blast and panicle blast is based on the Disease forecasting handbook issued by the Plant Protection Division, Ministry of Agriculture and Forestry region of different environmental conditions, the blast disease occurred more frequently than expected from the number of the spores trapped in the reigon of low wind velocity, and the forecast value of disease occurrence in terms of trapped number of spores did not coincide with that of other reigon.

This might be caused by two factors; that is, one is that the spores are apt to stay easily at the inside of the plant canopy in the region of low wind velocity, therefore the disease occurs more frequently in spite of the few number of trapped spores, and the other is that, since the water drops on the leaf, which are necessary for the germination of the spores deposited on rice plant and for the formation of appressorium, do not easily disappear owing to the high humidity, the spore which can invade into plant may be increased in the low-wind velocity region.

Therefore, the number of trapped spores must be compensated because the diffusive and invasive rate of spores are variable owing to the difference of wind velocity by regions.

1) Compensation by the dispersal condition of spores

As Fig. 3 shows the distribution difference of spores by the trapping height on the paddy field affected with blast disease, the height of the maximum trapping position is about 15 cm above the water surface. The number of trapped spores decreases according to the increase or decrease of height from the maximum trapping position, and especially at the plant height, it decreases abruptly.

As to the vertical change of the number of trapped spores, it decreases rapidly at the near level of the plant canopy and decreases gradually above the canopy. As the vertical distribution of spores at the height above plant height is fairly available for the forecasting of disease, it was examined with regard to the wind velocity. When the wind velocity is high, the number of trapped spores decreases gradually according to the increase of height and when the wind velocity is low, it decreases rapidly.

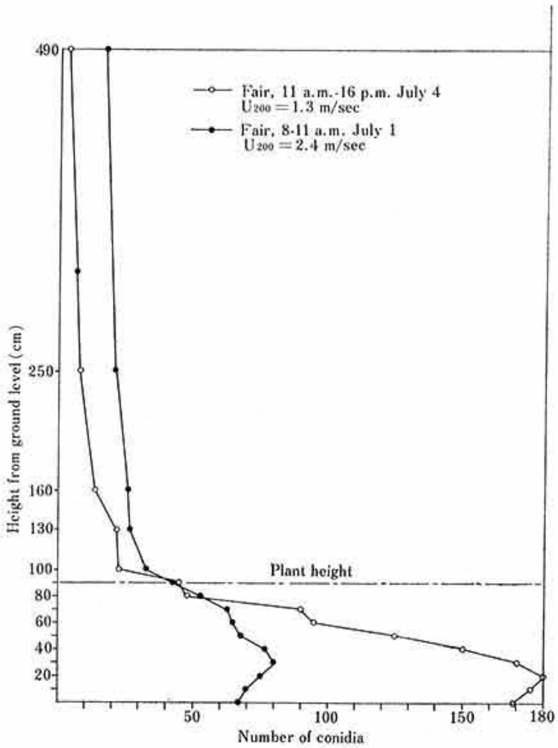

Fig. 3. Vertical distribution of conidia in and over the rice plant canopy in a paddy where the disease occurred

The vertical distribution of spores can be manifested by means of power type, and the logarithm of the number of spores vs. the logarithm of height gives a straight line. The inclination of this line is called the slope of vertical distribution, and the decreasing rate of the number of spores by height in the air is presumable from the inclination degree of this line.

When the wind velocity is high, the inclination of the line is small and the spores are in diffused condition, and when the wind velocity is low, the inclination becomes large and the spores are in stagnated condition.

Since there is an equation $m=1.80=0.33\ U_{200}$ which is related to the slope of vertical distribution of spores (m) and the wind velocity at the height of 2 m (U_{200}), the number of spores liberated from the plant canopy and the diffusion of spores can be presumed by means of the measurement of the wind velocity at the height of 2 m and of the number of

Table 1. Wind velocity and disease occurrence of leaf blast

Degree of disease severity of leaf blast	Yasuzuka-cho (Number of fields)	Takada City (Number of fields)	Kakizaki-cho (Number of fields)
$II_{0.2}$	19 (53)	30 (83)	32 (88)
$II_{0.5}$	2 (5)	2 (5)	2 (6)
III_1	1 (3)	2 (5)	1 (3)
IV_5	5 (14)		
IV_{11}	4 (11)	1 (3)	1 (3)
V_{25}	3 (9)	1 (3)	
V_{55}	2 (5)		
Wind velocity at the height of 2 m (m/s)	0. 1	0. 8	1. 5
Number of spores	14	141	5
Slope of vertical destribution of spores	1. 8	1. 5	1. 4

Note: The figures in ( ) are the percentage
Wind velocity, number of spores and slope of vertical distribution were investigated on July 1∼31 : a. m. 1∼2 a. m. The figures are the daily average

spores at any height in the space over the plant height.

As shown in Table 1, spore trapping was performed in the three regions of different wind velocity, and the possibility of disease forecasting was investigated in consideration of the diffusion condition of spores.

The wind velocity in Yasuzuka-cho, a town in a mountainous region, is very low; in Kakizaki-cho, a coastal town, it is very high; and in Takada City, a town in plain land, the wind velocity is mediocre.

As to the leaf blast in paddy field, in Yasuzuka-cho, a town of low-wind velocity, various grades of disease occurrence can be seen, but in Kakizaki-cho, a town of high-wind velocity, not much disease occurs in every paddy field. The slope of vertical distribution of spores was investigated to get the spore distribution in these regions. As the result, it was 1.8 in Yasuzuka-cho of low-wind velocity and 1.4 in Kakizaki-cho of high-wind velocity.

Therefore, spores do not diffuse much in Yasuzuka-cho but are apt to stay inside the plant canopy, and consequently the different grade of disease occurrence may be caused among paddy fields due to the difference of susceptibility of rice plant. On the contrary in Kakizaki-cho, spore diffusion is very strong and spores disperse uniformely over a large area.

Therefore, the density of dispersed spores becomes diluted resulting in a distribution of the paddy fields slightly affected by disease.

On the other hand, the maximum degree of disease severity of leaf blast in each town were III_2–IV_{11} in Yasuzuka-cho, IV_{11} in Takada City and $II_{0.5}$ in Kakizaki-cho, while the number of spores trapped in each town were 14, 141 and 5 respectively.

Therefore, it is impossible to forecast the degree of disease severity from the number of trapped spores.

Then the number of trapped spores was divided by the wind velocity in consideration of the diffusion to compensate the trapped number.

As the result, the compensated numbers were 140 in Yasuzuka-cho, 176 in Takada City and 3 in Kakizaki-cho which were well fitted to each degree of disease severity.

2) Compensation by the number of invasive spores

The deposition rate of spores on rice plant is low in strong wind and high in weak wind. The part of a plant on which spores can easily deposit are the obverse at the center or tip of middle and lower leaves developed horizontally. These deposited spores adhered on leaves without being removed by wind and rain.

The spores, which are flying in the air, possess high germinating abilities notwithstanding the flying height or time, and when they are deposited on the rice plant, they germinate in the water drops formed on leaves. The appressorium formation begins at 5–6 hours after deposition under the temperature range of 16–28°C during the disease outbreak season of leaf blast.

The water drops formed on leaves can be classified into raindrops, dewdrops and guttation drops. Guttation drops are formed soon after sunset and dewdrops begin to appear around 8 p.m. and they disappear about 8 a.m. next day owing to wind or temperature risen by sunrise. They disappear earlier than usual when it is windy at night.

Therefore, the appressorium formation is greatly affected by the time of spore deposition or by weather. When the duration of the presence of water drop is not sufficient for the appressorium formation, protoplasm coagulates and spore dies as soon as the water drop disappears.

Since the spore, which once touched water drop, dies when the water drop dried, the lifetime of spore may be just one day duration from the disappearance of water drop on the leaf to the disappearance next day.

Consequently, when it is fine, the rate of the germination and appressorium formation of the spores, which deposited on rice plant during the period from the disappearance of water drops to 2 a.m. of next day, is very high and there are many chances of disease occurence.

The period of presence of water drops differs by cultivation practice and topology and it is longer on the paddy fields of dense planting or on the shady area between mountains.

Therefore, there are much possibilities of appresorium formation and disease occurrence in such area.

The disappearing time of water drops on leaves differs by the position of field in several tens of paddy fields surrounded by a valley.

As to the relation between the positions of paddy fields and disease occurrence, an order from the most severe occurrence to low one may be established as follows; (1) the field at the inmost part of the valley where the sun rises later and it becomes shady earlier, (2) the east side of the valley where the sun rises later but it becomes shady later, (3) the west side of the valley where the sun rises earlier and it becomes shady earlier and (4) the opened area in the valley where the sun rises earlier and it becomes shady later.

Therefore, besides the length of the duration of the presence of water drops on leaves, the lateness of the disappearance of water drops is also an important factor for disease occurrence.

This is due to the fact that the maximum dispersing time of spores is at 0–4 o'clock, and weather condition of a small area affects strongly on the time of water drop formation, and the topographical difference becomes less effective.

The state of the appressorium formation can be presumed by the disappearing time of water drop by means of an equation which shows the relation between the disappearing time (T) and the formation rate of appressorium (A) as hereunder;

$A=3.4T-19.8$ (T is possible to be the time until 12 o'clock)

On the other hand, the formation and disappearance of dewdrops and guttation drops in a vast area can be presumed by wind velocity. Generally, there is very little yearly change in the disappearing time of dewdrops and guttation drops on a fine day in an area; therefore, no compensation of spore number is needed. But for an area composed of extremely different topography or of the paddy fields of different cultivation practices, the disappearing time of water drops must be considered for the forecasting.

The appressorium formation rate on fine day is 5% while that on rainy day is 40%; namely, the latter is eight times more than the former.

Since it was proved experimentally that the more firmly fixed the spore on basic substance, the better formed the appressorium, it was presumed that the raindrop falling on leaves makes the spores more adhesive and consequently makes better formation of appressorium, besides the long duration of raindrop presence on leaves on a rainy day.

Furthermore, the relation between rainfall time and the appressorium formation rate was investigated. That is, when it rained a whole day, the rate was 37%, and when it rained during a night, the rate was 35%. Both of them were fairly high rate.

But when it rained only in daytime, the rate was 10% and the rate on a fine or cloudy day was merely 2%. Therefore as for the condition of appressorium formation, rainfall at night is equal to the rainfall of a whole day, and the rainfall in daytime is almost equal to a fine or cloudy day.

Table 2. Relation between rainy days and degree of disease severity

Year	Rainy days during 30 days after the first occurrence of disease (day)*	Degree of disease severity
1967	17	5
1964	19	6
1961	20	7
1966	21	8
1962	22	9
1965	23	9
1963	23	10

Note: The standard degree of disease severity was set 1–10 grades, namely, 5: much, 6: severe, 7: commencement of stunting, 8: stunting, 9: severe stunting, 10: withering to death (Stunting is an acute symptom of blast disease)

* Obtained from the data of Takeda Meteorological Station

Table 2 shows the results of an investigation on the relation between the occurrence of blast disease and the rainy days during 30 days after the first occurrence. That is, the more the rainy days in a year, the more the disease occurrence in the year. And it was recognized that the disease occurred much in a year of more than 22 rainy days. If the forecast of the rainy days in a year is possible, the number of invasive spores may be presumable.

Conclusion

The specific points of this forecasting method may be summarized as follows;

1. Spores can be trapped at high positions because of high trapping efficiency. Therefore, a high accuracy can be obtained in the forecasting of the degree of disease severity in a vast area.

2. In the trapping of spores on a forecasting field, a field under standard cultivation may be well available for the forecasting, and the number of the spores trapped there can be used for the forecasting on ordinary paddy fields.

3. In the area with different wind velocity, such as mountainous or coastal region, the dissemination of spores and the duration of the water drop presence on leaves are not the same by the region. Therefore, it is possible to raise the accurracy of blast disease forecasting by the compensation of the number of trapped spores measuring wind velocity and by the forecasting of rainy days which affect very much the number of invasive spores.