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AD

TECHNICAL REPORT 69

SPREAD OF PIRICULARIA ORYZAE
IN SMALL RICE FIELDS
FROM FOCI OF DIFFERENT SIZES

Thomas H. Barksdale

Olin C. Miller

Marco A. Marchetti

Bernard R. Grove, Jr.

JULY 1965

UNITED STATES ARMY
BIOLOGICAL LABORATORIES
FORT DETRICK

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Fort Detrick, Frederick, Maryland

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Crops Division
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July 1965

FOREWORD

The authors are grateful for the assistance of the following people in conducting these studies: Dr. Karl S. Quisenberry, Consultant to Crops Division; the Commanding Officer, Avon Park Bombing and Gunnery Range, Avon Park, Florida; and Mr. Donald Hassfurther, Superintendent of the Avon Park Correctional Institution, who provided a team of unskilled laborers. Sgt. Haywood B. Williams was in charge of the labor team and the farming operations; he was also responsible for maintenance of vehicles and farm equipment, and for the procurement of local supplies. Lt. W.D. Brener participated in the experiment briefly. Dr. C.H. Kingsolver and Dr. C.G. Schmitt kindly reviewed the manuscript.

ABSTRACT

Race 1, isolate 429 of Piricularia oryzae was used to establish rice blast disease foci of 0.1-, 0.01-, and 0.0001-acre sizes in small fields of Gulfrose rice. Disease spread to the borders of the field with the largest focus within 14 days after inoculation, and to the borders of the field with the smallest focus within 48 days. Measurements of leaf-disease increase, spore concentration in the air, per cent panicle blast, and yield were made at sampling stations in the foci and along polar coordinates radiating from them.

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I. INTRODUCTION

There is available little quantitative information on the spread of rice blast, caused by Piricularia oryzae Cav. This study was performed in an attempt to quantitate and compare spread and subsequent buildup of the disease from foci of three sizes. The experiment was similar to a study of the spread of wheat stem rust from foci as reported by Schmitt et al.¹ of these laboratories in 1959.

II. MATERIALS AND METHODS

This study was made in 1964 at the Crops Division field experimental site located at Avon Park, Florida. Three fields were employed in the study and ranged in size from 1.1 to 1.7 acres. They were separated by about 2.5 miles to allow disease spread and epiphytotic development in each field to occur independently of happenings in other fields. The fields were located on an east-west line, and had been planted to crops in previous years. They were designated Paddy 4, Paddy 3, and Paddy 5, respectively, with Paddy 4 being the farthest east. Dimensions of the fields were: Paddy 4, 189 x 250 ft or 1.1 acre; Paddy 3, 189 x 260 ft or 1.1 acre; and Paddy 5, 205 x 362 ft or 1.7 acre.

The soil in this region is sandy, and leaching of mineral nutrients occurs rapidly. Experience has shown that fertilizer, especially nitrogenous fertilizer, must be applied periodically during the growing season to insure good growth of rice. The fertilizer schedule used for all fields is shown in Table 1.

The Gulfrose variety of rice, a commercially grown U.S. variety, was seeded in all fields by drill at 60 lb/acre on 28 and 29 April. A poor stand was obtained in Paddy 4, and this field was replanted on 11 May. It was impracticable to flood the fields because of the sandy soil. Paddies 3 and 5 were watered as needed by a sprinkler system; Paddy 4 was watered by ground seepage from a small ditch fed by gravity from a pond on a hill above the field.

Grassy weeds were controlled by an application of the herbicide propanil (Stam F-34) between 25 May and 1 June when weeds were in the 4-leaf stage. Although it is recommended that fields be flooded after application of propanil to prevent new weed growth, this was impossible and some regrowth occurred later, but not until the rice was well established. The areas used as foci in Paddies 3 and 5 were not treated with propanil because the effects of this chemical on blast are unknown.

TABLE 1. FERTILIZER APPLICATIONS TO FIELDS OF GULFROSE RICE

Date, 1964	Type of Fertilizer	Pounds of Nitrogen Per Acre		
		Paddy 4	Paddy 3	Paddy 5
27 April	8-20-20	36.4	36.4	23.5
13 May	Ammonium nitrate		33.0	31.1
19 May	Ammonium nitrate		33.0	31.1
27 May	Ammonium nitrate	33.0	33.0	31.1
2 June	Ammonium nitrate	33.0	33.0	31.1
16 June	Ammonium nitrate	33.0	33.0	
17 June	Ammonium nitrate			31.1
30 June	Ammonium nitrate	30.0	15.0	
17 July	Ammonium nitrate	30.0		
	Total nitrogen	195.4	216.4	179.0

The race of *P. oryzae* used to establish a focus of infection in each field was Race 1, Isolate 429, obtained from Dr. Latterell and Dr. Marchetti of these laboratories. This isolate came originally from Louisiana, and was highly pathogenic on Gulfrose in field tests conducted at Crowley, Louisiana in 1963.* The inoculum contained 272.5×10^6 spores per gram and was 55% viable. As the epiphytotic developed, cultures were isolated from diseased leaf and panicle specimens and identified as to race. Isolate 429 has a characteristic growth pattern, and when cultured under certain standard procedures by personnel familiar with the isolate, it can be reasonably well identified. Most isolations from field specimens were identified in this manner, but cultures from some specimens were further tested on differential rice varieties by methods described by Latterell, Marchetti, and Grove.²

In Paddy 4, the focus was established by bringing four one-foot-long boxes of rice bearing a total of 17 lesions into the center of the field on 3 June. Initial intensity of infection was thus 4.25 lesions per ft of row.

* Marchetti, M.A. Unpublished data and the associated Analyses 6171 (13 Feb 1964) and 6269 (15 July 1964), Crops and Biomathematics Divisions, U.S. Army Biological Laboratories, Frederick, Maryland.

The 17 lesions had resulted from an inoculation on 27 May of rice in several groups of boxes located in a 0.1 acre plot of Gulfrose near the laboratory building. Plastic tents had been placed over the boxes and spores atomized into the tents in a distilled water suspension. The tents remained in place until the following morning in an effort to confine the inoculum. Little disease occurred in the remainder of the 0.1 acre plot during the season, and relatively disease-free check yields were obtained from it.

Foci in Paddies 3 and 5 were established by inoculating directly in the field on 25 May. In Paddy 3, 0.18 g of inoculum preparation was suspended in 1 gallon of water. The suspension was applied with a garden sprayer on a 20 by 20 ft plot in the center of the field about 8 PM. About 7 PM, 1.81 g of inoculum preparation were suspended in 2 gallons of water and sprayed on a plot 66 by 66 ft in the center of Paddy 5. Inversion conditions prevailed in both fields at inoculation and the air was calm. Following these inoculations, a 12 hr dew period occurred with minimum night temperatures between 66 and 68 F near dawn.

One week after inoculation, observations in these fields indicated that the inoculum had not drifted farther than 2 ft outside of the area where it had been applied; at least, no lesions could be seen elsewhere in the fields. Initial intensity of infection in the focus of 400 ft², or 0.01 acre, at Paddy 3 was 17 lesions per ft of row. Initial intensity of infection in the focus of 4356 ft², or 0.1 acre, at Paddy 5 was 15.9 lesions per ft of row.

Stakes marking specific 1-ft-row sampling stations were placed at 25 ft intervals along lines running N, NE, E, SE, S, SW, W, and NW from the center of each focus to the border of each field (Fig. 1). In addition, sampling stations were located along lines running NNE, ENE, etc., at 25 ft intervals beginning 75 ft from the center. In Paddy 3, additional markers were placed 6 ft from the center on lines running NE, SE, SW, and NW, in order that there would be more than one sampling station in the focus. Disease measurements were taken at these stations as often as possible, at least once a week. One measurement was in terms of lesions per ft of row, which was made until lesions became so numerous as to make such counts difficult or meaningless. A second measurement, a severity rating in terms of per cent tissue diseased,³ was begun as soon as severity reached about 1% and was continued throughout the season. In a few instances both kinds of measurements could be made simultaneously. Disease measurements at a particular station were identified by the direction and distance from the center, e.g. NE 50 refers to the station 50 ft away from center in the NE direction.

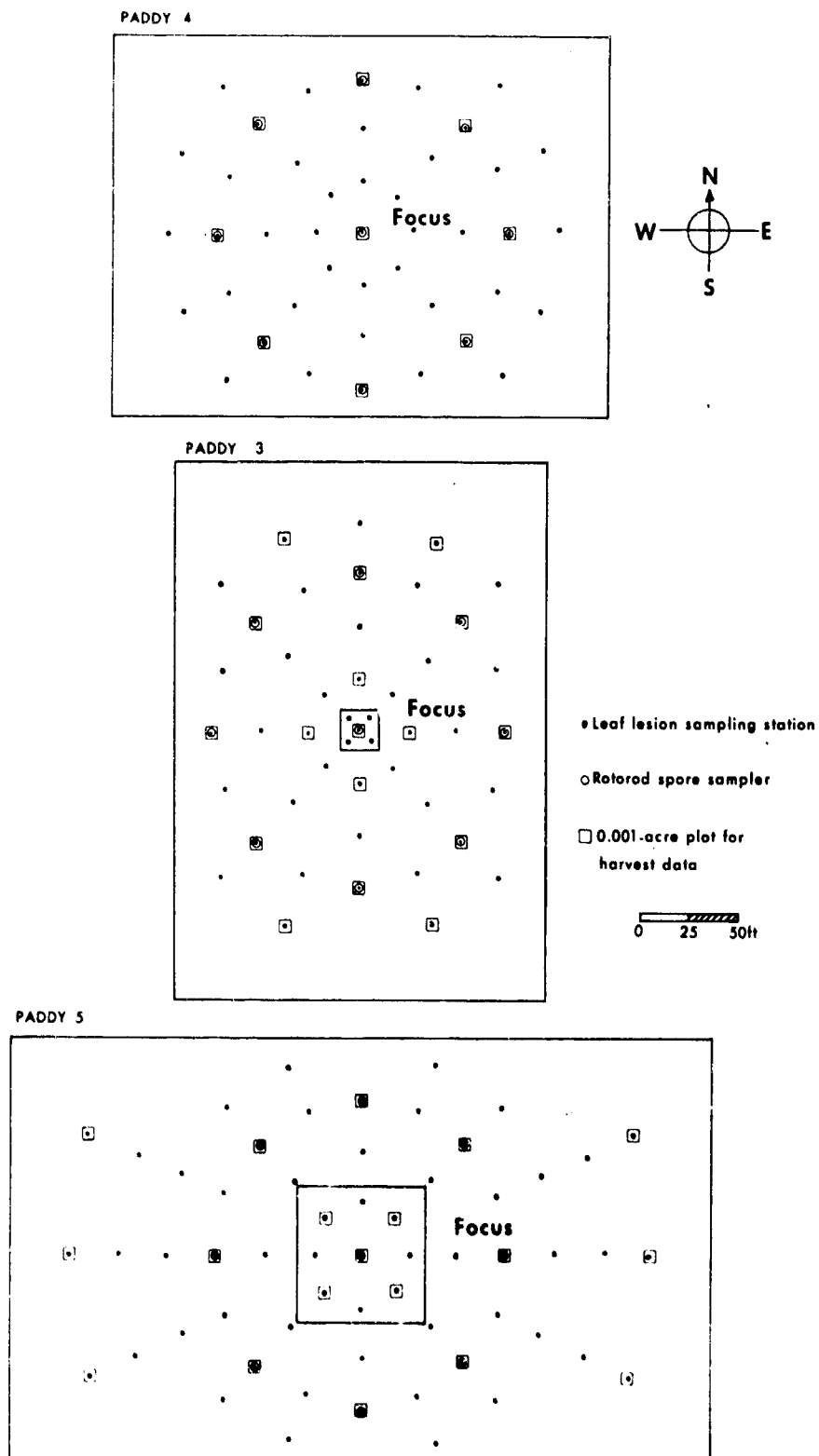


Figure 1. Plot Diagrams of Paddies 4, 3, and 5 Showing Location of Disease Focus, Leaf Lesion Sampling Stations, Rotorod Spore Samplers, and Plots from which Panicle Blast and Yield Data were Collected.

From the disease measurement data obtained, rates of disease increase (r) were calculated according to van der Plank's formula:⁴

$$r = \frac{2.3}{t_2 - t_1} \left(\log_{10} \frac{x_2}{1-x_2} - \log_{10} \frac{x_1}{1-x_1} \right)$$

In this formula, t stands for time in days, x is the proportion of tissue affected at these times, and the correction factor (1-x) is used to allow for the amount of healthy tissue available for infection which decreases as disease increases. The severity rating percentage was divided by 100 to effect the change to "proportion of tissue affected" for x_2 ; for x_1 the proportion of tissue affected had to be estimated from lesion counts. From the data obtained in Paddy 5, the average of 40 corresponding observations of both severity rating and lesion counts at certain sampling stations between 8 and 17 June indicated that one lesion was about equal to 0.00886% severity or a proportion of tissue affected equal to 0.0000886.

Some movement of personnel in the fields when data were collected and when fertilizer was applied could not be avoided. Precautions were taken, however, to lessen the danger of inadvertent spread from movements of workers in the fields. No laborers were permitted to work in any field unless they were wearing clean clothing that had not been worn in some other field, and if more than one field was entered on the same day the field with the least amount of disease was always entered first.

A roto-bar spore collector⁵ was placed one meter above the ground in the center of each field (therefore, also, in the center of each focus) and at the 75 ft sampling stations located N, NE, E, SE, S, SW, W, and NW (Fig. 1). These collectors operated for one hour between 3 and 4 AM each morning, and the roto-bars were collected and new ones put out about 10 AM each day. A rubber cement adhesive was used on the collecting surface of the bar. A 1-cm length on each exposed bar was examined under high magnification (430X) with a vertical illuminator; this was usually done during the afternoon of the day of collection.

A hygrothermograph and maximum-minimum thermometer were placed in an instrument shelter on the ground at the edge of each field. A Taylor dew meter⁶ was placed on sod nearby, and a rain gauge was mounted on a post 2 ft above the ground.

Data on the per cent panicle blast and on grain yield were obtained from the 0.001-acre plots located as shown in Figure 1. A light-weight frame 6.6 x 6.6 ft, was placed so that the sampling station that had been used to collect leaf lesion data was in the center of the 0.001-acre yield plot. Within the plot, panicles in the row containing the

sampling station, and in adjacent rows, were examined for panicle blast until a 200-panicle sample had been counted. Then a thresher was driven beside the plot, all tillers cut with a hand sickle, and the grain threshed. Harvesting was done in Paddy 4 on 20 August, in Paddy 3 on 19 August, and in Paddy 5 on 18 August. Grain samples were bagged and taken to a warehouse where they were air dried on screens for 4 or 5 days. The samples were threshed again to remove any remaining trash, and then their weights and volumes were determined.

III. RESULTS

A. SPREAD

Spread in Paddy 4 was first noted on 13 June, 17 days after inoculation or 10 days after bringing diseased plants into the field to establish the focus. One lesion was observed 2 ft W from the center (about 1 ft W of the edge of the focus) and another was seen 2 ft N from center. Then on 16 June, 20 days after inoculation, a lesion was spotted 5 ft E and another 15 ft S. Twenty-three days after inoculation, one lesion was seen at 40 ft between NE and ENE, one at 12 ft W, and one at 115 ft WSW near the border of the field. Thirty-five days after inoculation lesions began to appear at some of the sampling stations established at the beginning of the test; after 48 days lesions could be found everywhere in the field. Figure 2 shows the pattern of disease spread from the focus in Paddy 4.

Spread from the larger focus at Paddy 3 was noted first on 11 June, 17 days after inoculation of the focus; disease appeared at a greater distance and was more severe than in Paddy 4 during the same time interval. Spread had occurred in all directions. The farthest distance from center at which a lesion could be found was N 76, E 20, SE 23, S 23, SW 20, W 40, and NW 26. Lesions began to appear at many of the sampling stations 22 days after inoculation, but not until 35 days after inoculation did disease occur everywhere in the field. Figure 3 shows the pattern of spread from the focus in Paddy 3.

Spread from the 0.1-acre focus in Paddy 5 was first noted on 5 June, 11 days after inoculation, as one small young lesion at SSE 100. By 8 June, 14 days after inoculation, disease had spread to the borders of the field in all directions, although the highest lesion counts were in the quadrant from NE to NW. The 5-day period between 31 May and 4 June was the time when lesions in the focus would have been sporulating and providing the inoculum that caused the spread observed on 8 June; on the first three days of this period winds were mostly from the S, SE, or SW.

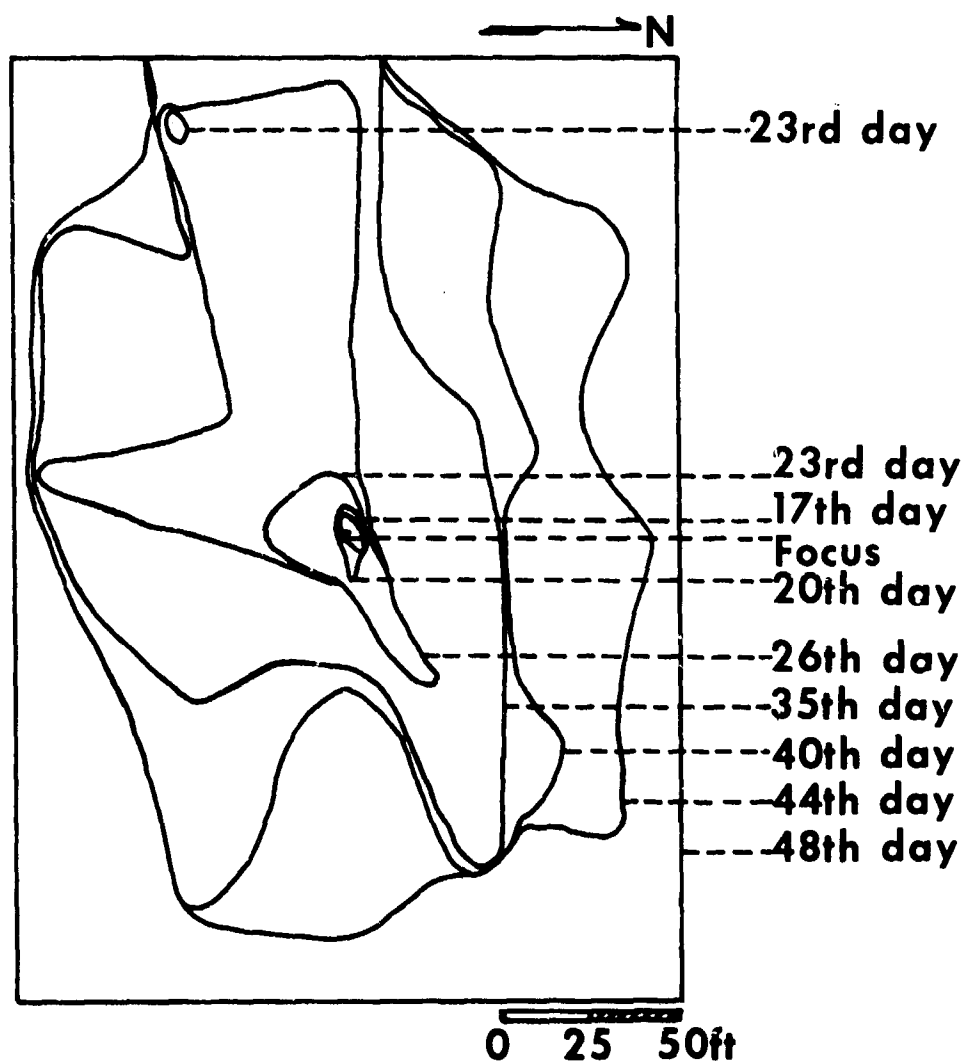


Figure 2. Spread of Rice Blast in Paddy 4 Showing Limit of Disease Occurrence on Indicated Days after Inoculation of the 4 ft² Focus.

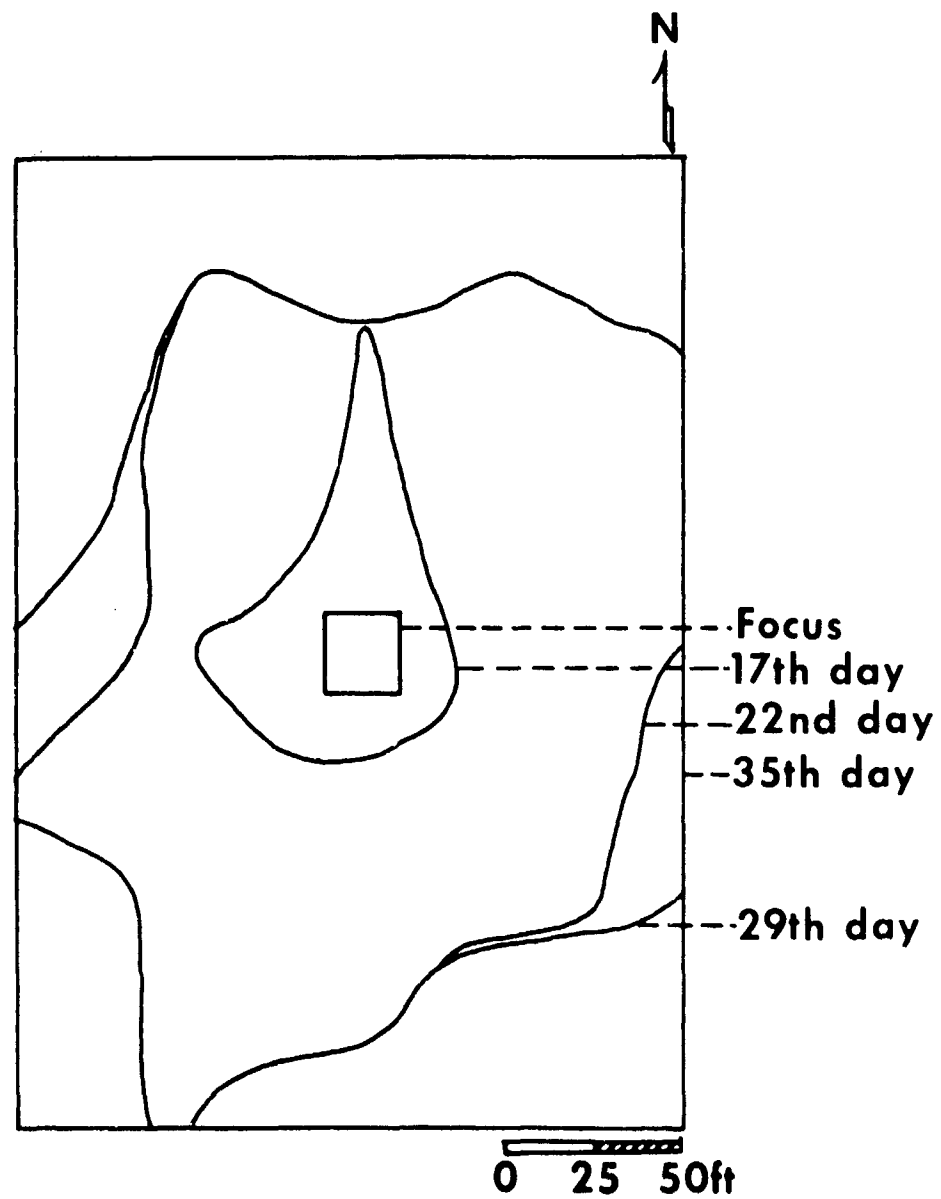


Figure 3. Spread of Rice Blast in Paddy 3 Showing Limit of Disease Occurrence on Indicated Days after Inoculation of the 0.01-Acre Focus.

The data on spread can be summarized as follows:

	<u>Paddy 4</u>	<u>Paddy 3</u>	<u>Paddy 5</u>
Area of focus (in acres)	0.0001	0.01	0.1
Days from inoculation of focus to first observation of:			
Spread	17	17	11
Spread to 100 ft in some direction	23	22	14
Spread to all borders of field	48	35	14

B. BUILDUP

Disease increase within the focus at Paddy 4 occurred to a very limited extent, and although new lesions appeared the amount of disease present in the focus remained about the same throughout the season, perhaps in part because of the loss of some lesions through natural attrition of older leaves. The disease severity rating in the focus never rose above 1%.

Disease severity within the focus of Paddy 3 was first seen to be increasing on the 14th day after inoculation and rose to an average rating of 24.6% by the 35th day after inoculation. Thereafter, severity decreased to 17.8% on the 51st day, which was just prior to panicle exertion. The rate of increase in the focus between the 10th and 31st days was 0.397 per day where $t_2 = 31$, $t_1 = 10$, $x_2 = 0.898$, and $x_1 = 0.00202$.

Disease buildup in portions of the fields outside the foci did not begin, of course, until disease had spread to these portions. It is difficult to make any generalizations about this buildup, but sometimes buildup at a given sampling station was related to the time at which disease first appeared and to the amount of disease first observed at that station. For example, in Paddy 4, disease was first noted at a few stations 35 days after inoculation, and the station, W 75, with the highest lesion count on that day, later had the highest severity rating at the end of the epiphytotic. In Paddy 3, buildup at most stations outside the focus began between the 22nd and 29th days, and eight of the nine stations having 10% or greater disease severity at the end of the epiphytotic had more disease initially than did any of the other stations in this field. Disease buildup within and outside the focus at Paddy 5 is shown in Figure 4, where the time at which leaf disease severity ratings of 50% or greater occurred are shown for various portions of the field.

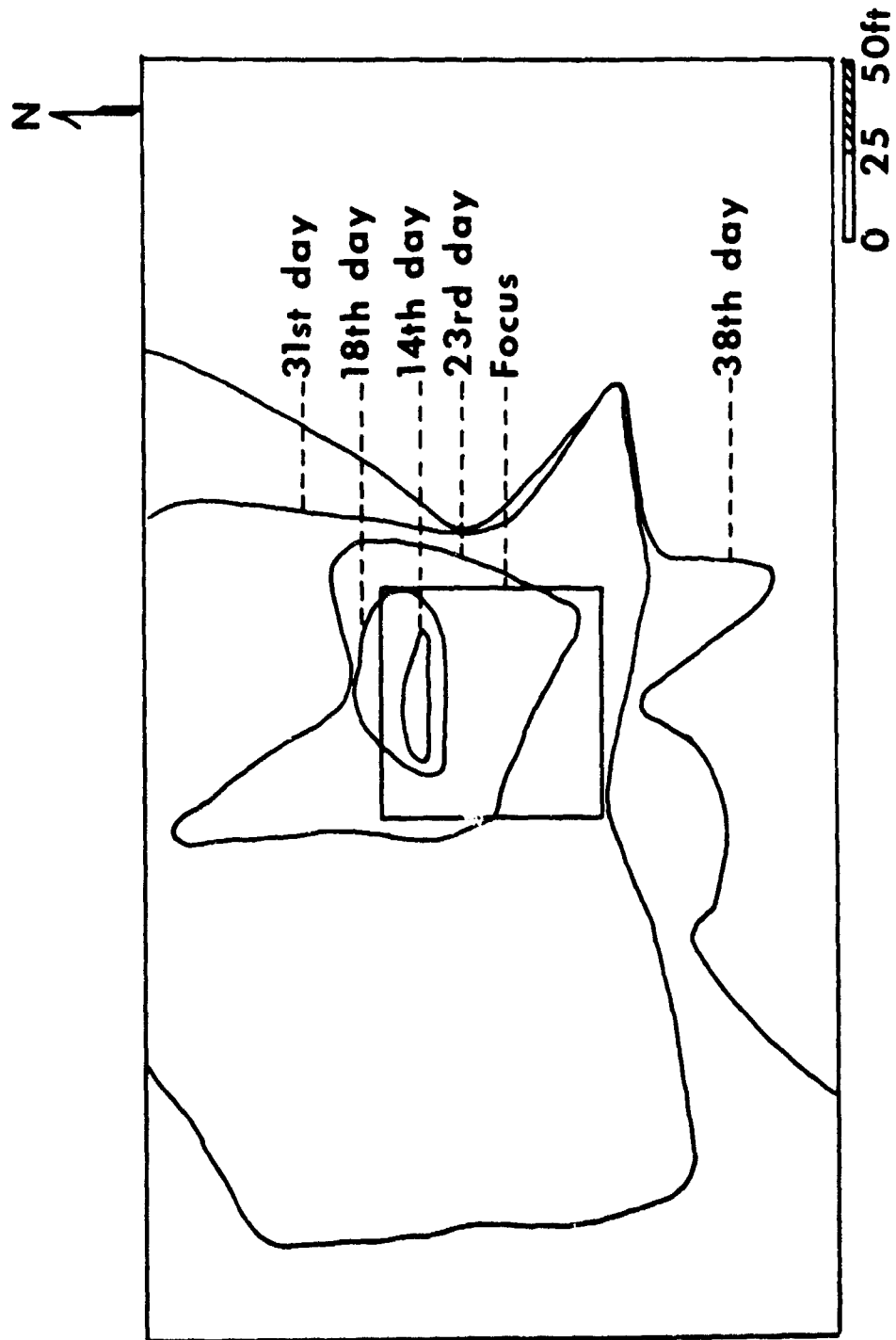


Figure 4. Increase in the Portion of Paddy 5 Containing Rice Blast Leaf Disease Ratings of 50% or Greater with Number of Days after Inoculation of the 0.1-Acre Focus Indicated.

There was a vast amount of variation in disease behavior from place to place within these fields, and data from several sampling stations in Paddy 5 illustrate the kind of variation found (Table 2). At some stations, disease became severe quickly and the plants were nearly killed, e.g., N 75, WSW 150, and NNW 75. At most stations, however, disease followed the more typical course of a rice blast epiphytotic as described in a previous report,³ where disease severity increases during the tillering growth stage and decreases somewhat when new susceptible tissue is no longer being produced, e.g., N 50, ENE 125, and S 50. In a few places, disease reached a certain severity and then the plants seemed to recover briefly until new tissue was produced and became infected, as at station E 75 and NW 50. At a few stations, plants had little disease at any time during the epiphytotic, e.g., E 125 and SW 100.

Instead of considering buildup in foci and other portions of fields separately, there is good reason to consider buildup and disease occurrence by taking whole fields as the unit of comparison. Certainly farmers in considering their profit or loss at the end of a year consider whole fields. Leaf disease data at all sampling stations (both within and outside the initial focus) were averaged for each date and these averages converted to logarithms and plotted against time (Fig. 5). The field with the largest focus initially had the greatest amount of leaf disease throughout the growing season, the field with the smallest focus initially, the least.

C. PANICLE BLAST AND GRAIN YIELDS

The use of the term panicle blast throughout this report implies that whole panicles were affected either by the occurrence of one lesion in the vicinity of the neck or by several lesions occurring elsewhere on the panicle. A panicle was not considered blasted if only a few of its grains were affected by the disease.

Panicle exsertion occurred in Paddy 4 between 26 July and 6 August; by harvest on 20 August an average of 94% of the panicles were blasted. The average yield of rough rice in the 0.001-acre plots (located as shown in Fig. 1) was 191 g which is equivalent to 421 lb/acre. The average weight of one cup ($\frac{1}{2}$ pint) of rice was 55.2 g.

TABLE 2. EXAMPLES OF DISEASE MEASUREMENT DATA FROM SELECTED SAMPLING STATIONS LOCATED OUTSIDE THE FOCUS OF PADDY 5

Distance and Direction from Field Center	Days from Inoculation of the Focus on 25 May									
	11		14		18		23		31	
	Lesions ^a		Lesions	SR% ^b	Lesions	SR%	Lesions	SR%	Lesions	SR%
N 75	0	157	<1	8	959	8	40	75	90	95
WSW 150	0	0		<1	30	<1	4	50	90	98
NNW 75	0	143	<1	6	798	6	40	80	90	95
N 50	0	273	2	25			45	65	65	55
ENE 125	0	14	<1	<1	42	<1	1.5	8	12	10
S 50	0	3	<1	<1	58	<1	5	15	45	25
E 75	0	28	<1	<1	66	<1	5	35	6	15
NW 50	0	441	5	10	1173	10	50	70	75	50
E 125	0	4	<1	<1	14	<1	271	2	1.5	4
SW 100	0	0			0		1	2	4	1

a. Leaf lesions per foot of row.

b. Severity rating is an estimate of the percentage of tissue diseased.

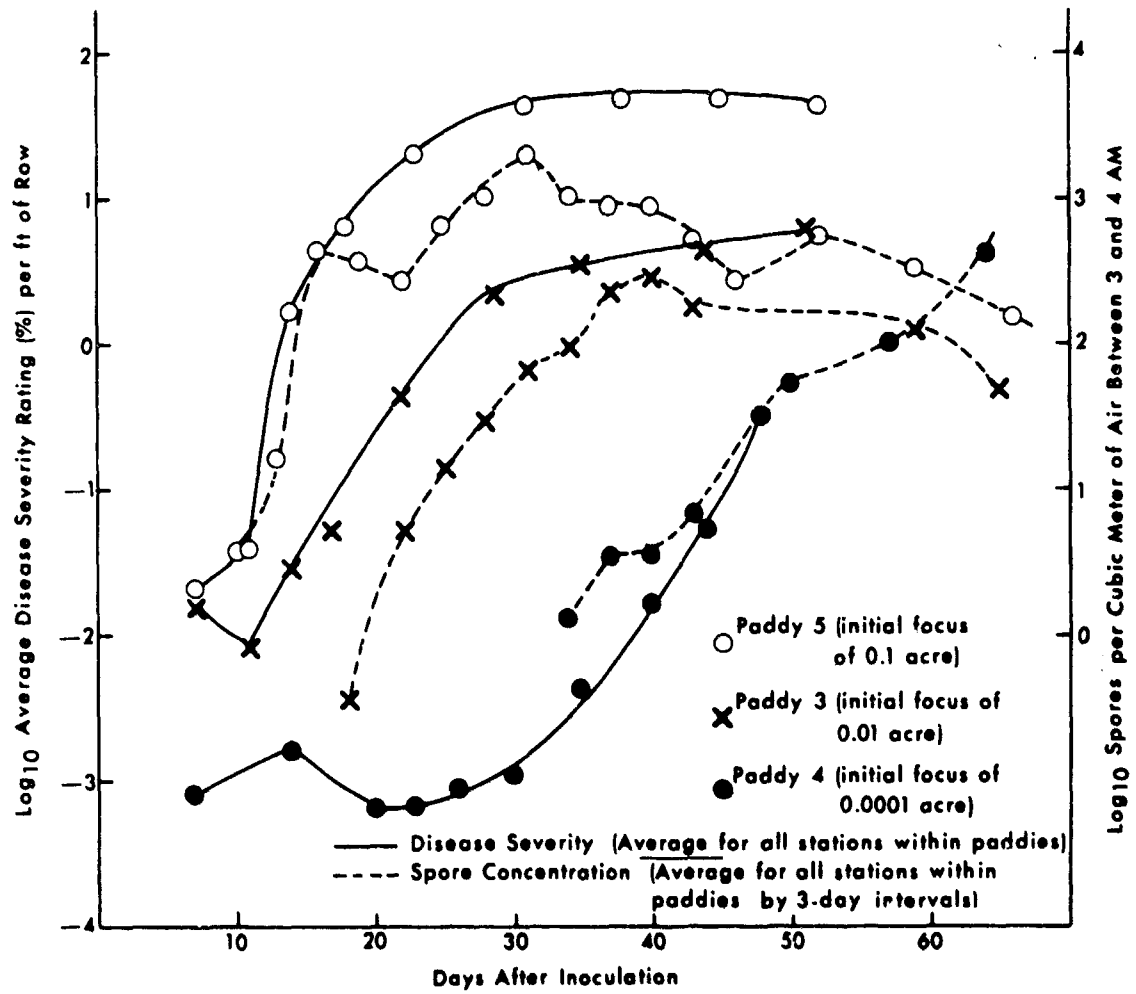


Figure 5. These Curves Illustrate the Relationships Between Severity of Leaf Disease and Spore Concentration.

Panicle exertion occurred in Paddy 3 between 17 and 29 July; by 10 August an average of 64.3% of the panicles were blasted. The paddy was harvested on 19 August and the average yield of rough rice in the 0.001 acre plots was 414 g, which is equivalent to 913 lb/acre. The average cup weight was 79.9 g.

Panicle exertion occurred in Paddy 5 between 17 July and 2 August, and on 12 August an average of 68.3% of the panicles were blasted. Paddy 5 was harvested on 18 August and the average yield of rough rice in the 0.001-acre plots was 239.21 g, which is equivalent to 527 lb per acre. The average cup weight was 89.3 g.

A small plot of Gulfrose near the laboratory provided three nearly disease-free check plots of 0.001-acre size. The average panicle blast was 1% and the average yield of rough rice was 1241 g, equivalent to 2736 lb per acre. The average cup weight was 132.9 g. If one takes 2736 lb per acre as a control, reductions in yield of rough rice in Paddies 4, 3, and 5 were 84.6, 66.6 and 80.7%, respectively.

D. SPORES IN THE AIR

Spore sampling data (Table 3) are given in terms of the average (for all 9 stations in each field) number of spores actually counted on the roto-bar for a distance of one cm under high magnification (430X). This figure is as good as any calculation made from the counts for the purpose of comparing fields. To convert the actual count to spores in a m³ of air during the hour of sampling, multiply the count shown in the table by five. When this conversion is made, averaged for all stations in a field by three day intervals, and plotted as in Figure 5, a relationship between disease severity on the plants and spore concentrations over them can be shown.

In Paddy 4, the first spore was collected at SW 75 on 21 June, 25 days after inoculation, but no spores were collected for the next 8 days. Beginning on the 34th day after inoculation, some spores were collected every day, although not always at every station. Not until 17 July, 51 days after inoculation, was there a moderate spore load in the air over all nine stations at Paddy 4. This load was comparable to that found in Paddy 3 by the 33rd day after inoculation and in Paddy 5 by the 15th day after inoculation. In general, spores were first consistently collected on the roto-bars located outside the focus at about the same time disease appeared at sampling stations outside the focus.

TABLE 1. THE AVERAGE (FOR 9 STATIONS) NUMBER OF SPORES OF *P. ORYZAE* COLLECTED ON A 0.053cm² PORTION OF A ROTOMAR BETWEEN 3 AND 4 AM

Date	Paddy					Date	Paddy				
	4	3	5				4	3	5		
June 3		0	0.7			July 1	0.4	50.9	153.9		
4		0	0.6			2	0.6	55.7	243.8		
5		0	1.4			3	0.8	70.9	162.5		
6		0	2.6			4	0.9	55.1	187.6		
7		0	1.6			5	0.8	43.9	136.3		
8		0	6.1			6	1.1	22.6	141.8		
9		0	69.9			7	0.5	51.8	89.7		
10		0	147.8			8	0.3	29.1	94.6		
11		0.1	62.2			9	2.8	17.7	83.3		
12		0	50.9			10	1.0	1	24.8		
13		0.1	70.4			14	1.6	6	26.4		
14		0	104.7			15	5.7	2	134.8		
15		0.1	48.3			16	3.2	11	126.7		
16		0.5	23.3			17	27.5	9	73.7		
17	0	2.7	109.8			21	4.8	2.0	3.0		
18	0	4.8	207.1			22	10.4	37.6	81.2		
19	0	3.3	113.6			23	37.8	11.4	65.8		
20	0	1.0	138.2			24	22.6	27.6	37.0		
21	0.1	6.6	233.2			28	47.0	6.0	19.0		
22	0	5.0	204.3			29	93.0	9.0	31.2		
23	0	7.1	197.3			30	89.5	14	45.0		
24	0	7.6	320.0			31	81.4	1.0	16.6		
25	0	16.1	415.5								
26	0	16.9	509.3								
27	0	24.4	310.8								
28	0	30.6	207.6			Aug 4	46.4	5.2	7.2		
29	0	5.3	85.1			11	9.6	2.0	0.2		
30	0.5	34.1	196.2			12	4.4	0	0		

During the first part of the period of panicle exertion, the spore load was about the same in Paddies 4 and 5, but tapered off at Paddy 5 toward the end of the period. Spore load in the air over Paddy 3 was definitely less than that over either of the other two fields during the time of panicle exertion.

E. WEATHER

For each field, records of minimum temperature and length of dew period were compared with the lower 95% confidence limit of a curve indicating minimum values of these two parameters needed for infection.³ When conditions on any night seemed limiting for infection, the hygrothermograph records for that night were examined and an average night temperature was calculated. When this average night temperature and dew period were then compared with the lower confidence limit of the minimum curve, it appeared that almost every night in all fields had a combination of values of dew and temperature that were favorable for at least some infection to occur. Those few nights when conditions were marginal if not actually limiting for infection were: Paddy 4 - 7, 8, and 10 June; Paddy 3 - 16 June; and Paddy 5 - 8, 16, and 25 June, and 21 July.

F. RACE OF PATHOGEN

Leaf lesion specimens collected 7 days after inoculation from the center of the foci in Paddies 3 and 5 were identified in culture as Race 1. Leaf lesion specimens collected on 8 June 100 ft from the center of Paddy 5 at eight compass directions (N, NE, E, SE, S, SW, W, and NW), and specimens collected on 23 June 75 ft from the center of Paddy 3 at the same compass directions were all identified in culture as Race 1. From Paddy 4, leaf lesion specimens collected on 21 July from center, N 75, E 75, S 75, and W 75, were identified in culture as Race 1.

An isolate from one leaf lesion from an unknown location in Paddy 4 collected after panicle exertion was tested on differential rice varieties and proved to be Race 1. Seven isolates from neck lesions were tested on differential varieties and proved to be Race 1. These neck lesions were collected at the following locations: Paddy 4 - center, N 75, and E 75; Paddy 3 - center and ESE 75; and Paddy 5 - S 75 and NE 75.

IV. DISCUSSION

The use of a 0.1 acre focus in a field of only 1.7 acres as in Paddy 5 gave little information about the distance of spread. Because the first observation of spread in this Paddy was a lesion near the edge of the field, one cannot be certain that in a much larger field a lesion would not have been seen at some greater distance from center. Another limitation of small fields for spread studies is that they do not permit the observation of the establishment of secondary foci. Although the air does not carry most spores far from their source and we see a gradient of infection away from the original focus, we would expect some spores to settle far outside the boundary of infection that spreads from the original focus and to establish new foci of infection.

The initial intensities of infection in the foci of Paddies 3 and 5 were about the same. The disease in the smaller focus increased at a slower rate (0.222 vs. 0.397 per day) and caused less leaf damage (a maximum severity rating of 24.6% vs. 89.8%) than did disease in the larger focus. A possible explanation is given by the theoretical considerations of van der Plank.⁴ He calculated the percentage of air-borne spores lost from square plots of different sizes under wind conditions of normal and low turbulence. More of the spores produced in small foci travel outside the boundaries of such foci than do spores produced in larger foci, and fewer spores result in less disease.

It is difficult to explain why the percentages of panicle blast and yield loss were somewhat greater in Paddy 4, the field with the smallest focus initially, than in the other fields. One possible explanation lies in the timing of nitrogen applications. The final bi-weekly application of nitrogen in Paddy 4 was made 9 days before panicle exertion, while in Paddies 3 and 5 it was made 17 and 30 days, respectively, before panicle exertion began (Table 1). The effect of nitrogen in making rice more susceptible to blast is well known and has been demonstrated in the field by workers from these⁷ and other laboratories; it may be that the timing of this last application caused both flag leaves and panicles to be more susceptible in Paddy 4 than in other fields. Another explanation, the possibility that large masses of spores arrived in Paddy 4 at heading time from the other fields, does not appear very likely. The spore load in the air at Paddy 4 during the time of panicle exertion in that field, 26 July to 6 August, was greater than that over the other two fields during that time period (Table 3).

The percentage of panicle blast has sometimes been taken as a conservative estimate of yield loss^{8,3} and in one test there was a significant and high negative correlation coefficient between the actual grain yield and per cent panicle blast occurring on seven rice varieties.* In the present test, percentage of panicle blast would have been a conservative estimate for Paddies 3 and 5, but would have overestimated loss from Paddy 4.

The spore sampling data do not reveal whether the rotobar sampler as used in these tests will be useful for making predictions of disease occurrence. Spores trapped at any given location seemed to be more indicative of the amount of disease already present in the vicinity of the sampler than of any future disease occurrence. When averaged spore concentration and disease severity data for each are compared throughout the epiphytotic as in Figure 5, it appears that the $\log_{10}$ of the spore concentration in terms of spores per cubic meter of air between 3 and 4 AM at one meter above ground is roughly 2 logs greater than the $\log_{10}$ of the average leaf disease severity rating per ft of row. Whether this or a similar relationship will exist in other rice blast epiphytotic situations remains to be demonstrated.

Weather conditions were favorable for infection in all fields almost every night. Therefore, weather was probably not an important variable influencing the differences in spread, buildup, spore concentration in the air, and panicle blast observed among the three fields. One possible exception may apply to Paddy 4, where three days, June 7, 8, and 10, thought marginal or limiting for infection occurred close together and soon after the focus was introduced into the field. This might have hindered spread and buildup early in the epiphytotic and helped accentuate the differences in spread and buildup in Paddy 4 as compared to the other two fields.

It seems reasonably well established that the race used to establish foci of infection in these studies is the race that increased in the fields and that caused panicle blast and yield reduction at the end of the epiphytotics. Agreement between race used and race recovered is thus much better than in some previous field studies.³

* Dahlke, G.R. Unpublished data and the associated Analysis 6433 (5 Aug 1964), Crops and Biomathematics Divisions, U.S. Army Biological Laboratories, Frederick, Maryland.

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Race 1, isolate 429 of <u>Piricularia oryzae</u> was used to establish rice blast disease foci of 0.1-, 0.01-, and 0.0001-acre sizes in small fields of Gulfrose rice. Disease spread to the borders of the field with the largest focus within 14 days after inoculation, and to the borders of the field with the smallest focus within 48 days. Measurements of leaf-disease increase, spore concentration in the air, per cent panicle blast, and yield were made at sampling stations in the foci and along polar coordinates radiating from them.			

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