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TECHNICAL MANUSCRIPT 463

DIFFERENTIAL SUSCEPTIBILITY
OF RICE LEAVES AND PANICLES
TO PIRICULARIA ORYZAE

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DIFFERENTIAL SUSCEPTIBILITY OF RICE LEAVES
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ABSTRACT

Greenhouse tests of differential susceptibility of rice (var. Zenith) seedlings and panicles to Piricularia oryzae indicated that seedlings inoculated with race 11 (IA-2) were highly resistant, but the panicles were susceptible. When only panicle necks were exposed for inoculation, the percentage of necks blasted was high at boot stage but gradually decreased during exertion of panicle necks. Panicle ears were susceptible to blast from the time of exertion to maturation of grain.

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I. INTRODUCTION*

Rice blast, caused by Piricularia oryzae Cav., occurs in most rice-growing areas and is considered one of the most important fungal diseases of rice. This disease presents a threat to the world's rice industry, especially with the increasing use of pure-line varieties and high-nitrogen fertilizers in an effort to obtain higher yields. In the presence of a suitable host-pathogen combination with favorable environmental conditions for blast, serious epiphytotic are known to occur. Although fungicidal control of blast has provided considerable protection in some rice-growing areas, its use has not been technically or economically feasible in most countries. The best control measure for this disease is the use of resistant varieties notwithstanding the complexity of races of the pathogen to be considered in breeding programs.

Characteristic symptoms of the disease occur on rice leaves and on the various parts of the panicle. Of several lesion types occurring on young seedlings, large grayish eyespots indicate a highly susceptible reaction. Lesions may enlarge rapidly and cause early death of the entire plant. More often, however, leaf lesions do not result in death of the plant, but may support sporulation. Spores formed on these lesions provide inoculum that may contribute to panicle infection. Panicle infection may include infection of the rachis, spikelet, secondary panicle branch, primary panicle branch, and neck. Infected panicle necks may effectively prevent the yield of a tiller. However, the literature does not emphasize that early infection of other panicle parts may also result in empty glumes or lack of grain formation.

Breeding results based on the reaction of rice to blast in field nursery tests have been difficult to interpret because of the presence of pathogenic races. Atkins and Johnston¹ recognized this and based their breeding program on the reaction of varieties to specific races of the blast fungus. However, we were led to believe that Atkins and Johnston evaluated their genetic data on the basis of seedling reaction. Because some scientists have reported a lack of correlation between seedling and panicle blast,²⁻⁴ our study was initiated to determine if such differences occurred in Zenith, a variety whose reaction to certain pathogenic races is well known. Although instances of differential susceptibility of rice seedlings and panicles have been observed by others, many of these observations were made in field tests, and results have been difficult to interpret.

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Hashioka,³ in a study of blast resistance in rice, observed that most varieties native to the temperate regions were susceptible to leaf blast, but most of the varieties endemic to the tropical regions were quite resistant. However, the resistance of nodes, culms, and panicles was not so clearly recognizable.

Rangaswami and Subramanian⁵ used 10 rice varieties in studying the correlation between leaf and neck infection. They reported a positive correlation between leaf and neck infection when all 10 varieties were considered as a lot. In individual varieties, there was a positive correlation between the two types of infections in the more susceptible varieties. However, there was no correlation between leaf and neck infection in less susceptible varieties. They also noted that severe leaf infection in a variety was not always followed by severe neck infection. The presence of severe leaf infection and the lack of neck infection could be attributed to variation in such factors as relative humidity and atmospheric temperature. It was indicated that these factors may also be responsible for the absence of leaf infection and the subsequent development of neck infection. In spite of the possible importance of environmental factors in these infections, Rangaswami and Subramanian recognized that morphological and physiological properties of the plant could have been partly responsible for the variation in reactions to the two types of infections in the less susceptible varieties.

Chang, Wang, Lin, and Cheng² reported that the variety Pai-kan-*tao* was highly susceptible to neck infection but maintained a high degree of resistance in the seedling stage in all disease nurseries during 1960 to 1963. Although a number of U.S. varieties used in these experiments showed more resistance to leaf infection than to neck infection, the agreement between leaf and neck reactions in a large number of varieties was generally good.

In contrast to the findings of the previous investigators, Ono and Suzuki⁴ found that leaf blast resistance was not influenced much by environmental factors, but neck blast was to an extreme degree. They noted that some foreign and upland varieties were strongly resistant to leaf blast but not to neck blast. Early-eating varieties were generally susceptible to neck blast.

Takahashi,⁶ in reviewing the work of Hashioka and Abumiya on the genetic behavior of resistance to leaf and neck blast, stated that there were too few experimental results from which to draw any conclusions applicable to a practical breeding program. In effect, Takahashi suggested that the mode of inheritance of leaf and neck blast should be studied by infecting individual plants under controlled environmental conditions.

Ou⁷ reported that the percentage of infected peduncles under field conditions indicated the degree of susceptibility or resistance of a variety to neck rot. He stated that there was no precise method of testing a large number of varieties simultaneously for neck infection because varieties vary

in time of heading and resistance of peduncles increases with time after emergence. He noted that climatic conditions greatly affected the percentage of varieties infected in the field. Ou concluded that, because most investigators have used a limited number of varieties or have conducted experiments under natural field conditions, a generalization could not be made about the correlation of leaf blast resistance and neck rot resistance.

In later work, Ou and Nuque⁹ observed that no neck rot occurred in 205 varieties resistant to leaf blast. Three varieties susceptible to leaf blast developed 8.1 to 18.5% neck rot in the same field. They concluded that varieties resistant in the leaf stage were resistant to neck rot under field conditions. A high positive correlation was found between leaf blast and neck rot when varieties were artificially inoculated. The appearance in the field of neck rot on varieties that showed leaf resistance was attributed to the presence of different races of the pathogen.

From reviewing the literature on the differential susceptibility of leaves and panicles to blast, it became readily apparent that additional knowledge was needed for a better understanding of these infections. Not only is there a need for establishing a better correlation between leaf and panicle infection, but the significance of this phenomenon should be better understood. In the present investigation, these considerations were of paramount importance.

II. MATERIALS AND METHODS

The rice variety Zenith was used as the host plant. According to Johnston,⁹ Zenith originated as the progeny from one of several panicle selections obtained by Glen K. Alter from a field of Blue Rose near DeWitt, Arkansas, in 1930. Later Alter gave the panicles to C. Roy Adair for growing at the Rice Branch Experiment Station, Stuttgart, Arkansas. The grain was sown and the best rows were selected for further testing. A particular selection, Arkansas No. 141-8, was increased in field plots in 1934 and named Zenith. Zenith, an early maturing awnless variety with rough hulls, was distributed to growers in 1936. Upon its release, it demonstrated considerable resistance to blast. However, in recent years, the importance of Zenith has declined, due, principally, to the appearance of pathogenic races of Piricularia and also because of its pubescent hulls, which cause a dust and "itch" disagreeable to workers in harvesting and processing.

Plants used in this study were grown in 0.5-gallon clay pots in a humidity and temperature controlled greenhouse, where the temperature was maintained at about 29 C during the day and 22 C during the night. The relative humidity varied with temperature, but was approximately 60% during the day and 95% at night. Soil type, its preparation, and seed planting techniques were similar to those used by Latterell, Marchetti, and Grove.¹⁰ Under these conditions, the plants usually came into panicle after 100 days. To insure a ready source of host material, 15 pots of Zenith seed were planted each week during the course of this study. The panicles were tagged to denote stage of development on the day plants were to be inoculated.

Panicles were inoculated by treating with an atomized spore suspension of race 11 (IA-2), 1×10^6 spores per ml. These inoculations were made at the rate of 1 ml per panicle. Because it was desirable to study panicle damage due to neck blast independently of damage due to ear blast, a technique was devised that involved protecting either the ear or neck with dialyzing tubing (collodion membrane) depending on the purpose of the experiment. When panicle necks were to be inoculated, leaf sheaths were removed from an area down to approximately 2 inches below the base of the panicle. To insure that only the necks were inoculated, ears were covered with small bags prepared from 0.75-inch dialyzing tubing (collodion membranes). The tubing was cut in 8-inch sections, tied at one end, placed over the ear, then taped around the base of the ear with masking tape, thus leaving the necks exposed. The necks of these panicles were then inoculated with an atomized liquid spore suspension. After inoculation, plants were subjected to dew for 16 hours in dew chambers held at 26 to 28 C. These conditions seem to be nearly optimal for infection. Following incubation in dew chambers, the plants were transferred back to the greenhouse for further observation.

III. RESULTS AND DISCUSSION

A. COMPARISON OF LEAF AND NECK REACTION

Pathogenicity tests showed that both seedlings and panicles of Zenith were susceptible to U.S. races 1 and 7 of *P. oryzae*. Although 3-week-old seedlings of this variety showed the usual resistant reaction when inoculated with race 11, a race characterized by Latterell, Tullis, and Collier,¹¹ the panicles of these plants were highly susceptible to this race. Three-week-old Zenith seedlings inoculated with race 11 developed small pinpoint brown lesions after 4 to 6 days, indicating a high degree of resistance. Lesions indicating susceptibility on necks also occurred at 4 to 6 days after inoculation. However, to allow for a more complete expression of lesions, the final recordings were made 18 to 20 days after inoculation. The differential response of Zenith to seedling infection and panicle infection clearly demonstrates the importance of determining the reaction to blast at both stages of plant development.

B. INFLUENCE OF PANICLE AGE ON INFECTION

During the early phase of this study, we observed considerable variation in the percentage of panicles that became infected following different inoculations. At that time we were not making close observations on the various stages of panicle development, but were giving more attention to the age of the individual plants. However, we soon noted that the age of panicles, which was defined in terms of stages of development, was far more important in influencing disease incidence than plant age per se. Therefore, our first task was to devise a procedure for determining stages of panicle development. The primary considerations in establishing such a system were the relative extent of panicle exertion from within the leaf sheaths and the degree of grain maturation. The stages used were as follows:

- (iv) Panicle completely enclosed by leaf sheaths
- (iii) Panicle partly enclosed by leaf sheaths
- (ii) Panicle base appears at the same level as auricles of the flag leaf
- (i) Panicle base is clearly above the auricles of flag leaf
- (sd) Grain at soft dough stage
- (hd) Grain at hard dough stage

We found it convenient to use the incidence factor (percentage of necks blasted) in evaluating neck blast, but for evaluating ear blast, the following severity scale was used.

<u>Numerical Scale</u>	<u>Symptoms</u>
0	Apparently healthy
1	Less than 25% of the primary panicle branches blasted, little if any deformation of grain
2	25-50% of primary panicles blasted, little if any deformation of grain
3	50-75% of the primary branches blasted, grain only partially developed
4	75-100% of the primary branches blasted, grain only partially developed
5	More than 75% of primary panicle branches blasted, resulting in the failure of grain to form

We began to record the stage of development of individual panicles at the time of inoculation in order to follow the disease incidence and severity more closely. To obtain a better understanding of the panicle and neck blast syndrome, some knowledge of the period over which the plant is susceptible was desirable.

Hashioka³ found that necks of rice panicles became resistant to blast with age. In his experiments, panicles were inoculated at various stages of development from 2 days before heading to 16 days after heading. Panicle necks were inoculated after they were exposed by unfolding the leaf sheaths. He concluded that the necks of panicles were highly susceptible when still enclosed in the leaf sheaths but became resistant with lapse of time after heading. Although Hashioka's data showed a trend toward resistance with age, we were puzzled because the percentages of infected panicles in his studies were so low before and immediately after heading. In Hashioka's experiments, the average percentage of infected panicles ranged from 7.8 to 72.0% at 2 days before heading to 2 days after heading.

We initiated a similar test with Zenith in an attempt to better understand these relationships. Although the percentage of panicle necks blasted was high at boot stage, it gradually decreased during exertion of panicle necks. Necks showed a high degree of resistance by the time grain had reached the soft dough stage and were completely resistant by the time the grain had reached full maturity (Fig. 1).

To determine the period during which panicle parts other than necks would remain susceptible, panicles with intact leaf sheaths were inoculated. Panicle blast increased in severity with progressive exertion of the panicle to stage (ii). Our data showed that the disease severity on panicle ears peaked at stage (ii) and then dropped off considerably. However, it was significant to note that ears never became completely resistant with age; they remained susceptible from the time they were exerted to maturation of grain, in contrast to panicle necks, which became progressively more resistant as they matured (Fig. 1). Although a slight increase in ear susceptibility is shown (Fig. 2) from stage (i) to (hd), we believe that this increase is insignificant. Although ears clearly remained susceptible, we find it difficult to explain the apparent increase in ear susceptibility during the terminal stages of grain maturation.

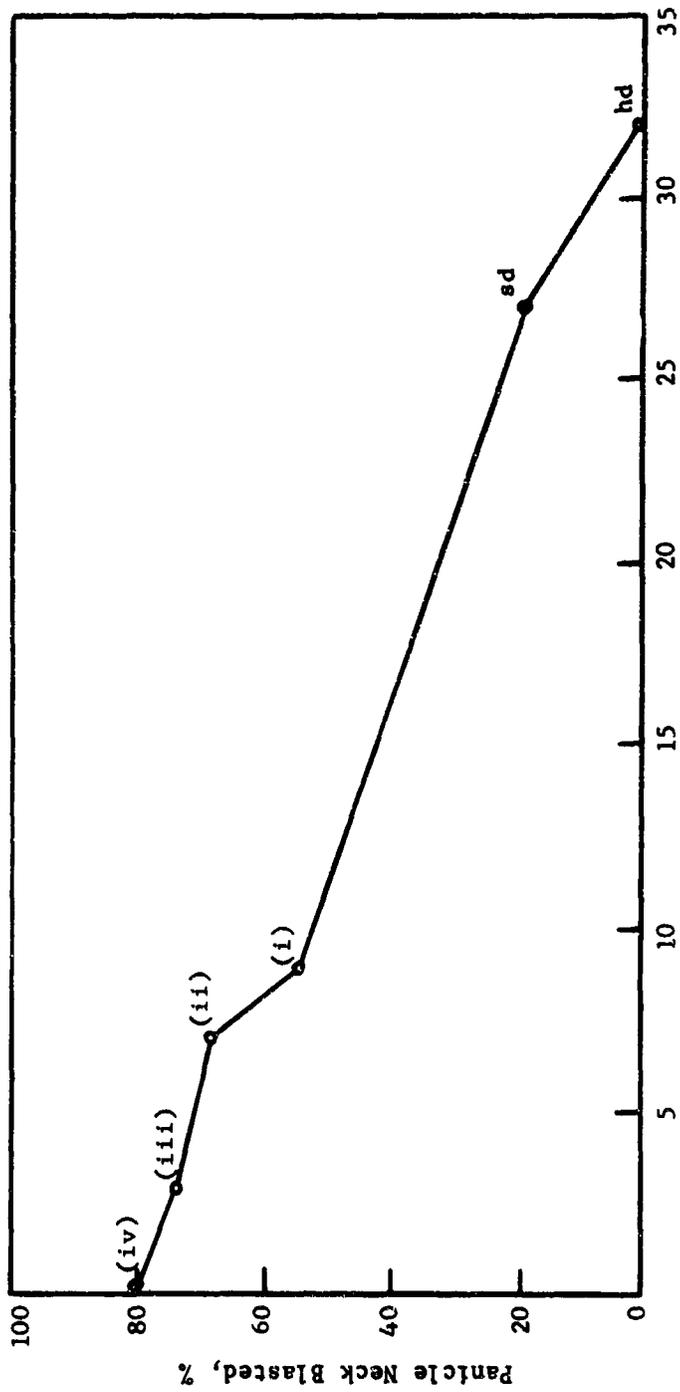


FIGURE 1. Stages of Particle Development Denoted by Days Between Stages. Each value for the percentage of particle necks blasted is based on a minimum of four replications and a total of at least 50 particles.

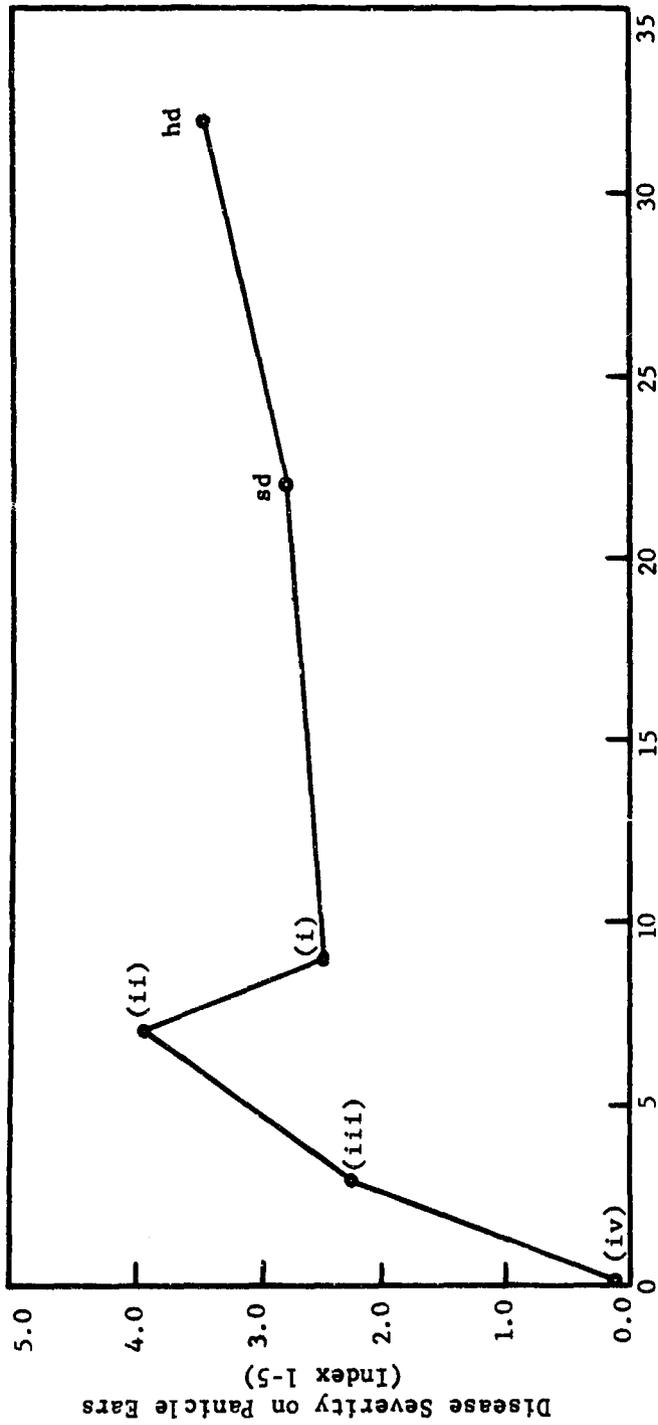


FIGURE 2. Stages of Panicle Development Denoted by Days Between Stages. Each value indicated for disease severity is based on a minimum of five replications and a total of at least 50 panicles.

It seems reasonable to infer that neck lesions can no longer be considered the most significant factor in the blast syndrome, for sporulating lesions that occur on other panicle parts probably are important sources of secondary inoculum. Furthermore, it seems likely that this secondary inoculum may incite lesions on ears and panicle necks of other susceptible plants. These findings have also indicated that neck lesions may occur as a result of infection in upper panicle parts. As we pointed out earlier, panicle necks of very mature plants (grain at soft dough through hard dough stage) are virtually resistant to infection when inoculated directly. However, neck blast may occur on mature panicles if earlier infection has occurred on panicle branches.

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