Role of Soil Type in Predisposing Banks and Other \textit{Pi-ta} Varieties to Rice Blast

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\textbf{ABSTRACT}

The high-yield varieties ‘Banks’ and ‘Cybonnet’, released to seed growers during 2004, contain the \textit{Pi-ta} R gene used in blast-resistant varieties for over 16 years. While Cybonnet fields were blast free, severe blast disease developed in drought-stressed Banks growing in a sandy production field in Clay County during 2004 and then again in sandy fields throughout Arkansas during 2005 and 2006. Race ‘IE-1k’, a rare but well researched minor race of the blast fungus \textit{Magnaporthe grisea}, was isolated from diseased Banks plants. Soil samples were collected from Clay County production fields and University of Arkansas research stations near Colt and Stuttgart, Ark. \textit{Pi-ta} and non-\textit{Pi-ta} varieties growing in these soil samples under either drought-stressed-upland or continuous-flood treatments were inoculated with race IE-1k. Leaf blast severity was highest in drought-stressed-upland treated plants and was reduced by the continuous-flood treatment. Soil samples were ranked according to blast severity over all varieties with the highest being an unidentified UA-PTES sandy loam sample followed by an UA-RREC Dewitt silt loam sample, a Corning 2005 Bosket FSL sample, an unidentified UA-PTES silt loam and, finally, a Corning 2004 Bosket FSL sample. This soil-type severity ranking was essentially the same, with minor variations, for each variety. Although leaf blast severity was higher with plants in specific soil samples, test results do not show increased blast susceptibility in drought-stressed Banks to be associated with a specific soil type. The test data show Banks to be more susceptible to race IE-1k than are other \textit{Pi-ta} varieties. Although susceptibility is intensified with drought stress and soil type, Banks lacks known blast-resistance genes \textit{Pi-kh} and \textit{Pi-ks}. These genes and/or other unidentified genes apparently confer much of the observed blast field resistance present in other \textit{Pi-ta} varieties. Blast field resistance, cumulative in susceptible
varieties, increases with magnitude and duration of root zone soil moisture until plants become highly resistant or immune to contemporary blast races. Field resistance, mediated by soil moisture, provides the primary rice-blast control mechanism utilized in Arkansas rice production.

INTRODUCTION

High-yielding varieties Banks and Cybonnet, released to seed growers during 2004, contain the major blast resistance gene (R gene) Pi-ta. In experimental tests and observation plots throughout Arkansas, Banks and Cybonnet expressed an increased rice-blast resistance over that of established high-yielding blast-susceptible varieties ‘LaGrue’ and ‘Wells’. Thus, Banks and Cybonnet were released as resistant varieties for use in blast-prone sandy production areas such as in northeast Arkansas. Since release, Cybonnet has remained blast resistant as expected. However, the Banks variety was severely damaged by rice blast over approximately 20 acres of a sandy production field in Clay County during 2004 (Lee et al., 2005a). Blast subsequently developed on drought-stressed Banks plants growing in sandy areas of production fields during 2005 and 2006.

Fungal isolates obtained from blasted Banks plants have been characterized as being the blast fungus Magnaporthe grisea race IE-1k. The Pi-ta R gene provides variety resistance to all common blast races except IE-1k. Discovered soon after the release of Pi-ta-based ‘Katy’ in 1989, race IE-1k was recognized as a potential threat to Arkansas rice production because the Pi-ta-based varieties are susceptible to race IE-1k in greenhouse tests. However, IE-1k appeared to be “poorly environmentally adapted” because incidence was limited to a few random plants in research field plots and Arkansas rice production fields. Race IE-1k-susceptible Pi-ta-based varieties including Katy, ‘Kaybonnet’, ‘Drew’, ‘Ahrent’, and now Cybonnet have been widely utilized in Arkansas production areas without any observed blast damage.

This research, funded primarily by the Arkansas Rice Research and Promotion Board, was undertaken to determine specific reasons race IE-1k damages the Banks variety but does not adversely impact other Pi-ta varieties. Results presented here exemplify our ongoing effort to better define and utilize blast field-resistance and investigate the consistent association of drought stress in sandy soils with blast in Banks.

PROCEDURES

Field-soil samples, taken from a depth of 0 to approximately 4 in., were: 1) a Bosket FSL soil collected immediately adjacent to the 2004 Corning blast-infected field-site; 2) a comparable Bosket FSL collected near 2005 Corning blast-infected production fields; 3) a sandy-loam soil (type unknown); 4) a silt-loam (type unknown) from the University of Arkansas Pine Tree Experiment Station (UA-PTES) rice blast nursery near Colt, Ark.; and 5) a Dewitt silt-loam from the University of Arkansas Rice Research and Extension Center (UA-RREC) pathology field nursery near Stuttgart,
Ark. Test varieties were: Wells, a widely grown blast-field-resistant variety that is subject to major yield reduction when drought-stressed; two well established blast-resistant Pi-ta varieties Drew and Ahrent; three newly released Pi-ta varieties Banks, Cybonnet, and ‘Spring’; and ‘Saber’, which is moderately resistant to resistant to race IE-1k in greenhouse tests. Samples were transported to the UA-RREC during 2005 for greenhouse pathogenicity tests using type Pi-ta-virulent race IE-1k (Zn 19). Tests were conducted concurrently for each soil type using techniques as previously reported (Lee et al., 2004; Lee et al., 2005b) where drought-stressed-upland or continuous-flood test conditions were established in 5-(H) by 6-(W) in. plastic pots. Blast severity for each plot was determined using the standard 0 to 9 visual rating scale where 0 = no disease and 9 = maximum lesion growth.

RESULTS AND DISCUSSION

All inoculated varieties exhibited leaf symptoms with severity being highest for plants growing in the drought-stressed-upland treatment and reduced by the continuous-flood treatment. Over all varieties, leaf blast severity was highest in upland plants growing in the PTES sand loam sample followed by the UA-RREC nursery, the Corning 2005, the UA-PTES loam and, finally, the Corning 2004 sample, respectively (Fig. 1A). Using drought-stressed-upland results, a comparable soil-type-severity ranking occurred, with minor variations, for each variety. Initial stages of the flood-induced-blast-field-resistance characteristic of the non-Pi-ta Wells was evident in continuous flood treatment (Fig. 1B). Banks, with overall higher blast severity ratings for the continuous-flood and the upland treatments, was the most susceptible and least flood-responsive Pi-ta variety tested (Figs. 1C, 1D, 1E, and 1F). Differences in leaf blast severity due to soil sample were evident but did not associate the blast damage in drought-stressed Banks with a specific soil type.

The reduced leaf blast observed with the continuous-flood treatment was consistent with previous research results and provided insight into the nature of blast field resistance (Lee et al., 2004). The reduced field resistance in Banks was less obvious because data are from a single short-term greenhouse experiment which did not capture the cumulative nature of blast field resistance. Under field conditions, blast resistance increases with flood depth and duration until certain varieties become highly resistant if not immune to all blast races. Flood-mediated root-zone dissolved oxygen determines blast severity in all susceptible varieties by controlling hormone production, plant metabolism, and plant morphology (Singh et al., 2004). These internal plant processes occur independently of external disease variables such as free water on leaves and high humidity, which impact spore dispersion, viability, and infection. Additional detailed experiments that closely monitor variable soil characteristics and blast severity are necessary to better define the role of soil type in predisposing rice plants to blast.

All Pi-ta varieties were susceptible to race IE-1k in greenhouse tests. When compared with type IE-1k, virulence and molecular differences were detected in IE-1k isolates from Banks (Jia et al., 2006; Lee et al., 2005a). However, these differences do
not explain the sudden and severe blast outbreak in drought-stressed production fields of Banks with not other stressed *Pi-ta* varieties. Although Banks was more susceptible to race IE-1k when drought-stressed, other aspects of the disease must be considered. The field-resistance phenomenon is poorly researched in rice. Perhaps the increased blast susceptibility of Banks can be explained by the absence of blast resistance genes Pi-kh and Pi-ks or other unknown minor genes essential for field-resistance development.

Regardless, new approaches must be developed to better predict and avoid events such as occurred with Banks. The immediate need is a fast, accurate assay for IE-1k severity and less reliance on the *Pi-ta* gene as a stand alone means to control rice blast. The problem is not limited to a single blast race or resistance gene however, because all current U.S. rice varieties are susceptible to one or more blast races and the blast pathogen frequently adapts to new R genes, techniques must be developed to define and utilize quantitative blast field-resistance in new varieties.

**SIGNIFICANCE OF FINDINGS**

Arkansas rice farmers suffer economic losses when rice varieties do not yield to their maximal capacity because of unexpected production problems such as rice blast disease. Results better define variables contributing to the blast disease in the “resistant” Banks, which contains the *Pi-ta* R gene. These data identify the need for improved field-resistance, which is the primary blast control mechanism utilized in Arkansas, and should guide researchers developing new rice varieties.

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**LITERATURE CITED**


Fig. 1. Comparison of leaf blast severity for Wells, Banks, Cybonnet, Ahrent, and Drew when growing in field soil samples with either continuous-flood or drought-stressed-upland treatments. A. Ratings averaged over all varieties for each soil sample, B. Wells ratings for each soil sample, C. Banks ratings for each soil sample, D. Cybonnet ratings for each soil sample, E. Ahrent ratings for each soil sample, and F. Drew ratings for each soil sample.