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Field efficacy of fungicides for management of sheath blight and narrow brown leaf spot of rice

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A B S T R A C T

Sheath blight (caused by *Rhizoctonia solani* AG1-IA) and narrow brown leaf spot (NBLS, caused by *Cercospora janseana*) are among the most important diseases affecting rice production in Texas and in other regions in the southern United States. Strobilurin fungicides have been used extensively to manage these two diseases, especially sheath blight. Unfortunately, heavy reliance on use of fungicides with a single mode of action has induced the development of the strobilurin-resistant isolates of *R. solani* AG-1 IA in the U.S. NBLS, once considered a minor disease in the U.S, is growing in its occurrence and severity, while little scientific information is available on NBLS management. This created an urgent need for identifying other effective fungicides with different modes of action. A 6-year field study was conducted on rice to evaluate the efficacy of newly registered and unregistered fungicides in comparison to common fungicides for management of sheath blight and NBLS diseases. Single applications of the fungicides containing azoxystrobin, propiconazole, azoxystrobin plus propiconazole, trifloxystrobin plus propiconazole, fluxapyroxad, pyraclostrobin, flutolanil and antibiotics (validamycin and kasugamcyin) were made at the late booting stage. Sheath blight and NBLS severities were rated prior to harvest. All the fungicide treatments were effective in reducing sheath blight severity compared to the untreated control in each year. Propiconazole and fluxapyroxad were more effective in reducing NBLS than other fungicides. Along with reduced sheath blight and NBLS severities, fungicide-treated plots had higher yields than untreated plots.

1. Introduction

Rice (*Oryza sativa* L.) is a primary staple for more than half the world's human population, and second most widely cultivated food crop after wheat (FAO, 2015). In 2016, global milled rice production reached 498 million metric tons (FAO, 2016) and the U. S. produced 7.5 million metric tons of rice on 1.27 million hectares, approximately half of which was exported (Childs, 2017). Rice production in the U.S. is concentrated in Arkansas, California, Louisiana, Mississippi, Missouri, and Texas. Plant diseases are one of the major causes of yield losses in rice. On average, 12% yield reduction is attributed to diseases in Texas rice production annually (Zhou and Jo, 2014).

Sheath blight is the most important rice disease in the U.S. and is the second most important rice disease worldwide after blast (Groth, 2005; Zhou and Jo, 2014). The sheath blight fungus, *Rhizoctonia solani* Kuhn AG-1 IA ((teleomorph: *Thanatephorus cucumeris* (A. B. Frank) Donk)) survives from one crop season to another through sclerotia, mycelia in plant debris, and weed hosts (Kumar et al., 2009). Symptoms usually develop in the later tillering or early internode elongation stage of growth as oval-to-elliptical, green-gray, water-soaked lesions on the sheaths of lower leaves near the waterline. Eventually these lesions expand and the center of the lesions may become bleached with irregular tan to brown borders. Under favorable conditions, infection spreads rapidly to the upper plant parts. Heavy infection results in reductions in grain yield, quality and increased lodging of plants. Disease severity depends on the amount of inoculum, crop growth stage, environment, and variety susceptibility (Gangopadhyay and Chakrabarti, 1982; Savary et al., 1997).

Narrow brown leaf spot (NBLS) is another economically significant fungal disease of rice caused by *Cercospora janseana* (Racid.) O. Constant (Syn. *Cercospora oryzae* Miyake; teleomorph *Sphaerulina oryzina* K. Hara). This disease has been historically considered as a minor disease due to its sporadic occurrence (Tullis, 1937; Ryker and Jordan, 1940). However, severe outbreaks of NBLS occurred in recent years in Texas and Louisiana where climate is generally humid and warm (Groth, 2008; Yingling et al., 2006; Zhou and Jo, 2014). The NBLS pathogen attacks leaves, sheaths, internodes, panicle branches and glumes. On the leaves, this pathogen causes short, linear, narrow, brown lesions parallel to the leaf veins. Infection on the leaf sheaths results in a large, brown blotch or net blotch

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caused by the browning of the leaf veins. Light brown to tan discoloration of the internodal area above and below the node at the base of the panicle is another symptom. The NBLS severity varies from year to year and usually the disease peaks as rice approaches maturity, thereby causing premature death of leaves, sheaths and thus predisposing the affected plants to lodging (Biswas, 2006; Chakrabarti, 1964; Groth and Hollier, 2010; IRRI, 2009; Ryker and Jordan, 1940; Tullis, 1937; Ou, 1985; Zhou and Jo, 2014). NBLS disease tends to be more severe on late planted rice or in the ratoon (second) crop (Zhou and Jo, 2014). The NBLS pathogen is seedborne and overwinters in infected rice straw and stubble and spreads by wind-borne spores.

Employing integrated disease management consisting of the use of resistant or moderately resistant varieties, good cultural practices, and foliar fungicides, is an economic and effective means to reduce yield losses due to these diseases. One of the major goals of rice breeding programs in the southern U.S. has been to improve disease resistance. However, due to lack of available varieties with acceptable levels of resistance to sheath blight, and the development of new races of the NBLS pathogen, fungicides remain as an important option to control sheath blight and NBLS.

For many years, strobilurin fungicides have been the backbone for management of rice sheath blight in the U.S. It has been opined that *R. solani*, a pathogen that reproduces asexually, would not develop fungicide resistance or would be slow to develop resistance because of its nature of less genetic diversity compared to other pathogens that reproduce sexually (Robinson, 2013). Unfortunately, heavy reliance on strobilurin fungicides in rice for control of sheath blight and in soybeans (most common rotation crop for rice) for the control of Asian soybean rust over years, have continuously challenged *R. solani* populations (Groth, 2013; Robinson, 2013). As a result, the strobilurin-resistant isolates of *R. solani* were confirmed for the first time in 2011 and fungicidal resistance spread thereafter, causing rice farmers to lose a major sheath blight control tool in Louisiana (Groth, 2012). This led to U.S. EPA granting Louisiana farmers with emergency use access to the fungicide Sercadis® under Section 18 (BASF, 2012).

Planting resistant varieties and maintaining a sound fertility program are recommended for managing NBLS (Zhou and Jo, 2014). However, resistance is not durable as the pathogen tends to develop new races quickly (Sah and Rush, 1988; Groth, 2007), thus making chemical control likely. Benomyl (a systemic benzimidazole fungicide) was reported to be effective against NBLS (Groth et al., 1990). However, this fungicide is no longer available due to cessation of production by DuPont in 2001. In the U.S., fungicides are labeled for NBLS management (Wrather, 2010) in the main crop but not in the ratoon crop. In the 2006 epidemic year of NBLS in Louisiana, the azoxystrobrin fungicide Quadris was widely used but failed to control NBLS (Groth, 2013). In the following year, Louisiana growers turned to propiconazole-containing fungicides which effectively controlled NBLS (Groth, 2013). Efficacy of propiconazole (Tilt®) against NBLS was reported in a 2-year field study by Mani et al. (2016). Apart from these reports, very limited data on management of NBLS are available in the literature.

Increased occurrence of NBLS, limited availability of data on fungicide efficacy for NBLS, and reports of strobilurin resistance in *R. solani* AG 1-IA populations created an immediate need for considering new management options for these fungal diseases. The present study was conducted to evaluate the efficacy of various registered and unregistered fungicides with different modes of action for the management of sheath blight and NBLS.

2. Materials and methods

2.1. Field trials, disease assessment, and yield and milling quality determination

Field trials were conducted in a field of Crowley fine sandy loam soil (59% sand, 2% silt, 12% clay, 0.7% organic matter and pH 5.3) at the David R. Wintermann Rice Research Station, Eagle Lake, Texas from 2011 through 2016. Plots consisted of six 4.9-m rows spaced 19 cm apart. Susceptible (to both sheath blight and NBLS) rice cultivars 'Cocodrie' (2011) or 'Presidio' (2012, 2013, 2014, 2015 and 2016) were drill-seeded at 90 kg ha^{-1} on March 28th, April 5th, March 27th, April 10th, April 15th and May 6th in 2011, 2012, 2013, 2014, 2015 and 2016, respectively. The field trials were conducted in a randomized complete block design with 4, 8, 6, 6, 4 and 4 replications, respectively. Cultural practices in all the trials followed local recommendations (Way et al., 2014). The experimental areas were naturally infested with the NBLS pathogen. For sheath blight inoculation, *R. solani* AG 1-IA, an isolate obtained from a sheath blight-infested rice field in Beaumont, TX in 2010, was multiplied under laboratory conditions. *R. solani* AG 1-IA was inoculated on sterilized rice grain and rice hull mixture (1:3 vol/vol) in autoclavable plastic bags and incubated at room temperature for 2 weeks. The *R. solani* inoculum was artificially inoculated at the panicle differentiation (PD) stage by manually broadcasting approximately 450 ml per plot each year. Dates of inoculation were: June 17th, 11th, 11th, 13th, 19th and 28th in 2011, 2012, 2013, 2014, 2015 and 2016, respectively. Fungicides were applied to rice plots at 7–10 days after inoculation, using a CO_2 pressurized sprayer equipped with a boom of three TeeJet 8002 nozzles spaced 41 cm apart that delivered fungicide at 299 L ha^{-1}. These fungicides included sterol biosynthesis inhibitors (triazole fungicides- Tilt® 3.6 EC, Syngenta, Greensboro, NC), QoI inhibitors (strobilurin fungicides- Quadris® 2.08 SC, Syngenta, Greensboro, NC; Headline® 2.09 SC, BASF, Research Triangle Park, NC; and Equation™, 2.08 SC, Cheminova Inc., Research Triangle Park, NC), combination fungicides with sterol biosynthesis and QoI inhibitors (triazole plus strobilurin fungicides – Quilt® 1.04 SE and QuiltXcel™, Syngenta, Greensboro, NC; and Stratego®, Bayer, Research Triangle Park, NC), succinate dehydrogenase inhibitors (pyrazole-carboximide fungicide Sercadis®, BASF, Florham Park, NJ; and phenyl benzamide fungicide Convoy® 40 SC, Nichino America Inc., Wilmington, Delaware) and aminoglycoside antibiotics (Validamycin and Kasugamycin- Bellrod corporation, Barrio la Ronda, Calle las Damas, Honduras). Fungicide applications were made on June 28th, 2011; June 26th, 2012; June 21st, 2013; July 3rd, 2014; July 2nd, 2015; and July 18th, 2016. Prior to harvest, severity of sheath blight and NBLS was rated on a scale of 0–9 based on percent of plant tissue affected as described by Groth et al. (1990). At maturity, the center four rows of each plot were harvested using a plot combine on August 5th, 6th, 5th, 20th, 10th, and 29th in 2011, 2012, 2013, 2014, 2015, and 2016, respectively. Rough grain yield and moisture were determined. Final rough grain yields were adjusted to 12% moisture. Rough rice was milled to remove hulls and bran layers. Milling percentages comprising "head rice" and "total milled rice" were also determined. Head rice milling percentage defined as the mass of kernels retaining three-fourths or more of their original length after milling, is expressed as a percentage of the original dried rough rice mass. Total rice milling percentage defined as the mass of total milled rice, was also expressed as a percentage of the original dried rough rice mass.

2.2. Data analysis

Data on sheath blight and NBLS severities, grain yield and milling quality (percent head rice and total rice) were analyzed by generalized mixed linear model analysis (Proc Mixed; SAS 9.4, SAS Institute, Cary, NC) for differences due to various fungicide treatments. Mean separations were performed using Fisher's protected least significant difference (LSD) test at $P = 0.05$. From these mean severity and mean grain yield data, percent reductions in severity rating over untreated control and percent increase in grain yield over untreated control for various fungicide treatments were computed.

3. Results

3.1. Effect of fungicides on sheath blight severity

Sheath blight severity differed among fungicide treatments and in