Crop Protection 89 (2016) 259–264

Contents lists available at ScienceDirect

Crop Protection

journal homepage: www.elsevier.com/locate/cropro

Effects of combined application of potassium phosphite and fungicide on stem and sheath disease control, yield, and quality of rice

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ARTICLE INFO

Article history:
Received 29 March 2016
Received in revised form
26 July 2016
Accepted 2 August 2016
Available online 9 August 2016

Keywords:
Azoxystrobin
Ciproconazole
El Paso 144
Oryza sativa
Uruguay

ABSTRACT

Phosphite has been shown to suppress some diseases in different plant species but disease control in rice has not been investigated. In 2012/13 and 2013/14 potassium phosphite was sprayed at 1775 g ha^{-1} and 3550 g ha^{-1} in field plots of rice in Uruguay to determine if phosphite alone or in combination with label rates of a mixed strobilurin and triazole fungicide could be used to effectively control stem rot and aggregate sheath spot in irrigated rice. Six treatments consisting of different combinations of potassium phosphite alone or with a fungicide and an unsprayed control were assayed in one application at late-boot to early-heading. Phosphite alone in single and double rate slightly reduced severity and incidence of stem rot and produced a small yield increase over the unsprayed control. Fungicide at a 50% label rate with phosphite reduced stem rot severity and incidence to a similar level as the fungicide alone applied at the label rate. Disease severity was reduced by approximately 25% and incidence by 17–20% when compared with untreated control. Yield increase was 5% for both treatments over the unsprayed control. Fungicide combined with phosphite at single and double rates reduced stem rot severity by 40–45% and incidence by 34–38% when compared with untreated control, with yield increased by 10% over the unsprayed control and 5% over plots treated with a fungicide. These results indicate that a single application of potassium phosphite combined with fungicide can be used efficiently to manage of rice stem diseases.

1. Introduction

Rice (*Oryza sativa* L.) is one of the most important crops in Uruguay covering 167,200 ha with a total production of 1,348,000 tons during the 2013/14 growing season (DIEA, 2014), which represents approximately 7% of the national agricultural GDP over the past several years (Vasallo, 2014). Losses due to diseases are important constraints for rice production with blast and stem rot considered at the most important in Uruguay. Stem rot of rice caused by *Nakataea oryzae* (Catt.) J. Luo & N. Zhang, most commonly found in the sclerotial state (*Sclerotium oryzae* Catt.), is a serious disease occurring in most rice-growing regions of the world (Webster and Gunnell, 1992). The fungus survives between crops as mycelia or sclerotia in rice debris or into the soil. Disease severity is positively correlated with the number of sclerotia present in the upper layer of the rice field before planting (Webster and Gunnell, 1992). The sclerotia can survive unfavorable conditions buried in the soil and viable sclerotia can be recovered after as long as 6 years with an estimated half-life of 1.9 years (Ou, 1985). In Uruguayan soils with a long history of rice cultivation the number of sclerotia surviving is very high and over 6 sclerotia by g/soil were found with a low correlation with the subsequent disease level (Beldarrain and Ávila, 2009).

Stem rot development depends in weather conditions and management practices (Beldarrain and Ávila, 2009), although yield losses in Uruguay have been reported to be between 2 and 24%, depending on the year, cultivar and final disease severity (Ávila, 2000). When severity levels reach 50% based on a disease severity index (Ou, 1985), reported yield losses are approximately 10%, but these losses can reach 30% when severity increases to 80% (Ávila, 2000). Webster and Gunnell (1992) reported 10% yield losses as typical for stem rot, but also noted that yield loss can be as high as 75%.

Aggregate sheath spot and sheath spot of rice, caused by *Rhizoctonia oryzae-sativae* (Sawada) Mordue and *Waitea circinata* Warcup & P. H. B. Talbot (=*R. oryzae* Ryker & Gooch) respectively, are considered minor diseases of rice worldwide (Lanoiselet et al.,

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http://dx.doi.org/10.1016/j.cropro.2016.08.002
0261-2194/

2007). Aggregate sheath spot can be a very aggressive disease of rice in some regions and has become increasingly important in temperate rice-growing regions, for example California, south-eastern Australia and Uruguay (Lanoiselet et al., 2007).

The disease cycle for aggregate sheath spot and sheath spot is very similar to stem rot, with the pathogen overwintering as sclerotia or mycelium in the soil or in rice crop residues. The hydrophobic sclerotia float on water and after germination the mycelia infect the rice sheath at the water line (Lanoiselet et al., 2007; Ou, 1985). Some studies suggested that both *Rhizoctonia* spp. can infect the rice plant early in the season without apparent symptoms although controversy exists about the exact location where the initial penetration of the pathogen into the host occurs (Lanoiselet et al., 2007), as some authors have suggested this occurs through the inner sheath surface (Hashioka and Okuda, 1971), while others have suggested penetration occurs through the outer sheath surface (Marshall and Rush, 1980).

Aggregate sheath spot can cause yield losses as high as 20%, while sheath spot can reduce yields by up to 10% in field trials conducted in Australia (Lanoiselet et al., 2005). Yields losses ranging from 4% to 9% were reported in field trials in Uruguay for the tropical japonica cultivar INIA Tacuarí but without major quality losses (Ávila, 2001; Lanoiselet et al., 2007). In Uruguay, *Rhizoctonia* spp. appear to be more common in tropical japonica than indica rice cultivars (Ávila, 2001).

Several management practices are used to reduce the negative effect of stem rot and *Rhizoctonia* spp., including, the adjustment of N fertilization, seed density and cultivar selection (Webster and Gunnell, 1992). Some of these management practices are impractical depending on growing conditions and a fungicide application, mostly from late boot to early heading, is currently a common practice in farms with a long history of stem rot disease (Martínez et al., 2013). Extensive use of fungicides poses a significant concern for human health and environmental safety and thus new tools are needed in order to diminish the fungicide input in farms (Damalas and Eleftherohorinos, 2011).

Phosphites are alkali metal salts of phosphorous acid containing a metal cation such as Cu, K, Na, ammonium, or a non-metallic anion, like phosphite, hydrogen phosphite or dihydrogen phosphite (Deliopoulos et al., 2010). These salts are highly soluble, are absorbed rapidly by plants, and have a significant selectivity and systemic translocation (Guest and Grant, 1991). Phosphites, as a reduced form of phosphate, are registered as fungicides, fertilizers or biostimulants for crop production (Deliopoulos et al., 2010) and are registered as foliar fertilizers in Uruguay but have been used to control leaf diseases on different crops (SATA, 2013). Different studies have shown that phosphite does not provide phosphorous (P) to the plant, and as such, cannot complement or substitute P at any applied rate. Phosphite does not have any plant health effect on healthy plants (Thao and Yamakawa, 2009). Phytotoxicity of phosphite depends on the P nutrient status of the plants, and thus should not be used when plants are in suboptimal P nutrient status. Phosphites are known to control many plant diseases caused by chromista belonging to the Class Oomycetes, especially plant pathogens pertaining to the genera *Peronospora*, *Phytophthora*, *Plasmopara* and *Pythium* (Abbasi and Lazarovits, 2006; Cooke and Little, 2002; Deliopoulos et al., 2010; Orbović et al., 2008; Silva et al., 2011). Furthermore, control of fungal pathogens like *Alternaria* and *Penicillium* has also been reported in several studies (Reuveni et al., 2003; Yogev et al., 2006; Amiri and Bompeix, 2011).

While it is known that phosphites can manage several plant diseases, further research is needed to examine the compatibility of fungicides with phosphites to determine whether they can be used in mixtures and if there are useful interactions present. Previous reports indicated that potential synergism exists between phosphite salts and fungicides (Deliopoulos et al., 2010; Rosenberger et al., 2008). Therefore, the objectives of the present study were to evaluate: (1) the effect of different phosphite application rates on control of stem and sheath diseases of rice; (2) the interaction of combined phosphite and foliar fungicide application on the control of the these diseases; and (3) the response of phosphite or combined phosphite and fungicide application on yield and quality of rice grain.

2. Materials and methods

2.1. Experimental design and cultural practices

Two experiments were conducted during the seasons 2012/13 and 2013/14 at the Unidad Experimental de Paso de la Laguna, INIA Treinta y Tres in the Departamento de Treinta y Tres, Uruguay (33°16′21″S 54°10′48″W). The climate is temperate, moderate and rainy (type "C") with precipitation throughout the year (type "f"); in the hottest month the temperature is over 22 °C (type "a") (Instituto Uruguayo de Meteorología, 2014). These characteristics correspond to the Cfa climate type based on the Köppen-Geiger classification (Peel et al., 2007). The soil type is classified as a melanized solod of the "La Charqueada" Soil Unit based on Uruguayan soil classification (Altamirano, 1979).

Trials were drill-seeded on 7 November 2012 and 11 October 2013 into conventional tilled seedbeds at an average rate of 145 kg ha^{-1} with "El Paso 144", an indica type long grain cultivar. El Paso 144 was selected as it is the most widely planted rice cultivar in Uruguay, covering 35% of the rice area in the 2013/14 season (DIEA, 2014). Additionally this variety has high yield potential, but is susceptible to stem rot (Ávila, 2000). Experimental plots measured nine rows wide by 8 m-long, with a row spacing of 17 cm and 0.5 m wide plant-free corridor between plots.

Fertilizer management varied among years but N fertilization was based on recommendations for commercial farms. Phosphorous fertilizer was applied during the seeding stage according to local recommendations at 55 kg P_2O_5 ha^{-1} as Triple Superphosphate in 2012 and at 63.5 kg P_2O_5 ha^{-1} as Triple Superphosphate in 2013. In 2012 and 2013 the total N applied as urea was 65 kg N ha^{-1}, divided in two applications: a single preflood N application at the tillering stage (32.5 kg N ha^{-1}) and a single application at the beginning of internode elongation (32.5 kg N ha^{-1}).

Weed control practices varied across the two years depending on the density and weed species present. In 2012 weed control consisted of an application of penoxsulam [3-(2,2-difluoroethoxy)-N-(5,8-dimethoxy[1,2,4]triazolo[1,5-c]pyrimidin-2-yl)-α, α, α-trifluorotoluene-2-sulfonamide] 0.175 L ha^{-1}, clomazone [2-(2-chlorobenzyl)-4-4-dimethylisoxazolidin-3-one] 0.8 L ha^{-1} and pyrazosulfuron-ethyl [ethyl 5-[(4,6-dimethoxypyrimidin-2-ylcarbamoyl)sulfamoyl]-l-methylpyrazole-4-carboxylate] 0.1 kg ha^{-1}. In 2013 weeds were controlled with a tank mixture of picloram (4-amino-3,5,6-trichloropyridine-2-carboxylic acid) 0.1 L ha^{-1}, clomazone [2-(2-chlorobenzyl)-4-4-dimethylisoxazolidin-3-one] 0.8 L ha^{-1}, penoxsulam [3-(2,2-difluoroethoxy)-N-(5,8-dimethoxy[1,2,4]triazolo [1,5-c]pyrimidin-2-yl)-α, α, α-trifluorotoluene-2-sulfonamide] 0.175 L ha^{-1} and pyrazosulfuron-ethyl [ethyl 5-[(4,6-dimethoxypyrimidin-2-ylcarbamoyl)sulfamoyl]-l-methylpyrazole-4-carboxylate] 0.2 kg ha^{-1}.

The experimental design was a completely randomized block arrangement with six phosphite and/or fungicide treatments and a check without application and four blocks (replications). Potassium phosphite (71% w/v, P_2O_5 30% + K_2O 20%) was applied at a single (1775 g a.i. ha^{-1}) or double rate (3550 g a.i. ha^{-1}), according to the label recommendations for rice, as well as either with or without fungicide which consisted of azoxystrobin and cyproconazole