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AGRONOMIC PERFORMANCES OF BLAST INFECTED RICE VARIETIES UNDER SILICON APPLICATION

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AGRONOMIC PERFORMANCES OF BLAST INFECTED RICE VARIETIES UNDER SILICON APPLICATION

By

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Faculty : Agriculture

Rice blast (*Pyricularia oryzae* Carava [teleomorph*: Magnaporthe grisea* (Herbert) Barr]) is considered a major rice disease because of its wide distribution and extent of destruction under favourable conditions. The economical approach for controlling the blast disease is the use of resistant varieties. However, chemical control is the most widely used. Resistant cultivars have a limited effect due to the breakdown of resistance genes with increasing blast pathotypes overcoming rice resistance. While, continuous use of chemical fungicides also leads to the reappearance of resistant races of the pathogen. Silicon (Si) has been reported to increase the growth and yield of a broad range of crops and beneficial in controlling diseases caused by both fungi and bacteria in different plant species. To manage rice blast in an effective and sustainable way, all crop protection practices in future should consider new approaches such as using Si fertilizer. The objective of this study was to investigate the effect of Si on panicle blast disease and grain yield of resistant and susceptible rice varieties. Experiments were conducted under controlled and under field conditions on two rice variety, MARDI Siraj 297 (resistant) and MR 263 (susceptible). Results showed that under controlled conditions application of Si to rice plants decreased panicle blast severity as the Si rates increased from 0 kg/ha to 400 kg/ha as well as increased Si deposition in rice panicles. This strongly supports the hypothesis that application of Si to rice plant improved the resistance against panicle blast. The increase in Si density in rice panicle thus prevent against appressoria penetration of the blast fungus into the panicle. Results also showed that, non-structural carbohydrate decreased at 200 kg Si/ha in rice panicles that lead to decline in grain yield. Panicle blast disease was found under natural field conditions. The disease occurred in low levels incidence thus the effect of Si had no influence. The application of Si at reproductive stage (panicle initiation) improved production of grain, with concomitant increase in nitrogen uptake. Higher grain yield was associated with increased number of panicles per square meter and number of spikelet per square meter. The findings

in this study indicated that panicle rice blast disease can be managed with 245 kg Si/ha. This could reduce 24% of panicle blast severity and consequently increased the grain yield by 11%. Scientific evidence in the present study supports the beneficial use of Si as a fertilizer in rice cultivation in Malaysia.
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Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PRESTASI AGRONOMI VARIETI PADI DIJANGKITI PENYAKIT KARAH DENGAN PENGGUNAAN SILIKA

Oleh

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Penyakit karah padi (*Pyricularia oryzae* Carava [teleomorph*: Magnaporthe grisea* (Herbert) Barr]) merupakan penyakit utama padi kerana penyebaran yang luas dan kesan kerosakan teruk pada keadaan yang kondusif. Pendekatan ekonomi untuk mengawal penyakit karah adalah penggunaan varieti rintang. Walau bagaimanapun, racun kimia paling banyak digunakan. Varieti rintang karah mempunyai kesan terhad kerana gen ketahanan menjadi lemah dengan peningkatan patotip karah mengatasi ketahanan padi. Manakala, penggunaan racun secara berterusan membawa kepada kemunculan semula patogen yang tahan kepada racun kimia. Silikon (Si) dilaporkan dapat meningkatkan pertumbuhan dan hasil pelbagai tanaman dan bermanfaat dalam mengawal penyakit yang disebabkan oleh bawaan kulat dan bakteria. Untuk menguruskan penanaman padi dengan cara yang berkesan dan lestari, amalan perlindungan tanaman di masa depan harus mempertimbangkan pendekatan baru seperti penggunaan baja Si. Objektif kajian ini adalah untuk mengetahui kesan Si terhadap penyakit karah tangkai dan hasil padi bagi varieti rintang dan rentan. Eksperimen dijalankan di bawah keadaan terkawal dan di ladang ke atas varieti MARDI Siraj 297 (rintang karah) dan MR 263 (rentan karah). Hasil kajian menunjukkan, dalam keadaan terkawal, pemberian Si pada tanaman padi menurunkan keterukan penyakit karah tangkai dengan peningkatan kadar Si dari 0 kg/ha sehingga 400 kg/ha selari dengan peningkatan pemendapan Si pada tangkai padi. Ini menyokong hipotesis bahawa penggunaan Si ke atas tanaman padi meningkatkan daya tahan terhadap penyakit karah tangkai. Peningkatan pemendapan Si dapat mencegah penembusan appressoria kulat karah ke dalam tangkai padi. Hasil kajian juga menunjukkan, karbohidrat bukan struktur menurun pada kadar 200 kg Si/ha pada bahagian tangkai padi yang menyebabkan penurunan hasil padi. Penyakit karah tangkai dijumpai pada keadaan semula jadi. Penyakit ini berlaku pada tahap rendah dan tidak menunjukkan kesan dengan pemberian Si. Pemberian Si pada peringkat

pembiakan (peringkat bunting) meningkatkan penghasil padi selari dengan peningkatan pengambilan nitrogen. Hasil padi yang lebih tinggi dikaitkan dengan peningkatan jumlah tangkai per meter persegi dan jumlah spikelet per meter persegi. Hasil kajian dalam kajian ini menunjukkan bahawa penyakit karah tangkai dapat diatasi dengan pemberian 245 kg Si/ha. Ini dapat mengurangkan keterukan karah tangkai sebanyak 24% dan seterusnya meningkatkan hasil padi sebanyak 11%. Bukti saintifik dalam kajian ini menyokong penggunaan Si yang bermanfaat sebagai baja dalam penanaman padi di Malaysia.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
RCBD	Randomized Complete Block Design
DOA	Department of Agriculture
EDX	Energy Disperse X-ray
g	gram
ha	hectare
IRRI	International Rice Research Institute
keV	Kiloelectron volt
L	liter
LSD	Least Significant Difference
MARDI	Malaysian Agricultural Research And Development Institute
mL	milliliter
N	nitrogen
P. oryzae	*Pyricularia oryzae*
SAS	Statistical Analysis System
SEM	Scanning Electron Microscope
Si	Silicon
USDA	United States Department of Agriculture

CHAPTER 1

INTRODUCTION

Rice (*Oryza sativa*) belongs to the grass family (Gramineae). Rice is the staple food for Malaysians and is an important food security crop in most Asian countries. Self-sufficiency level (SSL) is around 72 percent of the total requirement of Malaysian populations. The total planted area in 2018 was 689,810 hectares which produced 3,064,822 tonnes of rice grain and generated about 1,975,770 tonnes of white rice. The average production in 2018 was 4443 kg/ha, about 19 percent higher than the rice production in 2017 (DOA, 2018). Even though rice production increased, the increase in Malaysian population has not made any changes of Malaysian SSL (Sharif, 2013). The total consumption of rice increased from 2.5 million metric tonnes in 1985 to 4 million metric tonnes in 2009 because of the increase in Malaysian population (Fatimah et al., 2011; Zainal Abidin, 2015). Rice industry in Malaysia is to ensure food safety, stable price, political stability and economic importance. Moreover, there are 296,000 rice farmers totally dependent on growing rice for their household income (Zainal Abidin, 2015).

One of the main concerns of the rice industry is the yield losses due disease problems. Blast disease (*Pyricularia oryzae* Carava [teleomorph*: Magnaporthe grisea* (Herbert) Barr]) is considered as a major rice disease in rice cultivation. Rice blast is a widely distributed pathogen of rice, could be found in any rice field. According to Fisher et al. (2012) rice blast disease occurs in 85 countries and causing 10-35% grain yield losses. In Malaysia, blast outbreaks are sporadic and difficult to predict thus blast control in the field is difficult. Grain yield losses causing as much as 50-70% once being infected by rice blast in Malaysia is common (Latiffah & Norsuha, 2018; Saad et al., 2004) and 50-70% in Philippines (Durgeshlal et al., 2019; Gianessi, 2014). In Indonesia about 12% of the total area of rice cultivation was reported to be infected by rice blast (Suryadi et al., 2013). The most effective and economical approach for controlling blast disease in rice is the use of resistant cultivars. Nonetheless, the use of such cultivars has limited success due to the breakdown of resistance genes with increasing biotypes breeds overcoming rice resistance. In addition to the cultivar-specific resistance breeding, chemical control is the most widely used method of effective plant disease management. Although they are effective in controlling the fungal infections in rice, public concerns about the use of synthetic fungicides are growing.

Silicon (Si) has widely been reported to increase the growth and yield of a broad range of crops and beneficial in controlling diseases caused by both fungi and bacteria in different plant species. Si is the second most ample element after oxygen in the earth crust (Heckman, 2012) and silicon dioxide form about 60% of the earth's crust, and it occupies more than 50% of the soil (Marschner, 1995). Despite its abundance in both soils and plants, Si is not considered an ‘essential’ element because Si could not meet Arnon and Stout's definition of essentiality (Liang, et al., 2015). Since most plants can be grown without Si many plant physiologists have considered this element as unessential (Epstein, 1999).

The Si-induced mechanism to improve plant resistance to blast disease takes place in the soil, root system and inside the plant. In rice, both radial transport and xylem loading of silicic acid (H_4Sio_4) are mediated by transporters Lsi1 and Lsi2 in roots and Lsi6 in shoots (Ma et al., 2006). Silicic acid absorbed by root cells is stored in the leaf epidermal cells, and after removal of water, the accumulated leaf silicic acid is condensed into hard polymerized silica gel ($SiO_2.nH_2O$) known as phytoliths (Tubana et al., 2016). Deposition of Si in rice plants in the epidermis of rice leaves is part of a plant defense system that acts as a physical barrier that efficiently increased rice resistance to rice blast (Rodrigues et al., 2015). The strength and kinetics of PR-1 accumulation, modulated by R-genes as well as Si, indicate the quantitative level of responsiveness of rice cells to rice blast infection (Rodrigues et al., 2005a). They explained that the differential accumulation of glucanase transcripts, peroxidase and PR-1 was associated with the inhibition of the spread of the fungus and the damage it caused to the leaf tissues. Moreover, Si deposition in plant tissues could also improve tolerance of rice plants to biotic and abiotic stress (Dai et al., 2005; Etesami & Jeong, 2018; Pati et al., 2016). In addition, Si increased rice resistance to leaf and neck blast, sheath blight, brown spot, leaf scald and stem rot (Datnoff et al., 1997).

Molecular screening of blast resistance genes on targeted four major resistance genes, Pi5, Piz-t, Pik and Pib showed that MR 263 contains only two genes Pik and Pib (Ab Razak et al., 2019). However, there is no study on resistant blast gene in MARDI Siraj 297. Based on genetic diversity of released Malaysian rice varieties using single nucleotide polymorphism (SNP) markers showed that MARDI Siraj 297 ((MRQ76 x P446)/P446) has highest similarity with MR 253 (Ab Razak et al., 2020). According to Ab Razak et al., (2019) MR 253 have three major resistance genes namely Piz-t, Pik and Pib. A major resistance (R) gene confers particular resistance to a pathogen race containing a specific avirulence (AVR) gene (Wang et al., 2008). Blast classification showed at least there are 22 pathogen race of rice blast in Peninsular Malaysia (Harun et al., 2013). According to Siti Norsuha & Latiffah (2019) the most common pathogen race in Peninsular Malaysia are P0.0, P0.2, P1.0, P2.0, P3.0, P7.0 and P9.0 and most of the pathogen race were isolated from MR 263 except for P0.2 and P2.0. On the other hand, there is no record of pathogen race isolated from MARDI Siraj 297. This could explain why MARDI Siraj 297 durable resistance to rice blast than MR 263.

Panicle blast causes direct yield losses because infected panicles are poorly filled with grains. Panicle blast is the most extreme blast disease than leaf blast because it happens late in the season when the farmer has spent all of his crop production inputs (Bastiaans et al., 1994). Application of nutrients at panicle initiation significantly increased in filled grains, 1000-grain weight and total grain yield (Bah et al., 2009) and increased flower number per panicle which is one of the most important traits in rice productivity determination (Ding et al., 2014). Si application increased the grain filling (%) and also improving crop yield (Cuong et al., 2017). Despite numerous studies on the role of Si, the question remains does Si contribute to disease defense and consequently improve plant growth and yield.

The use of resistant variety and Si application seem to be practical in controlling blast incidence. Therefore, the present study was carried out with a hypothesis that Si application reduces the severity of panicle blast and consequently improve rice growth and development. Hence the objectives are: (1) to study blast disease occurrence in naturally infected rice plant under field environments; (2) to study the effect of Si on rice blast severity on susceptible and resistant rice varieties under controlled conditions; (3) to study the effect of Si on panicle blast disease under field conditions.

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