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RESEARCH ARTICLE

Antifungal properties and phytotoxicity of ZnO nanoparticles – a genotypic dependent effect

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ABSTRACT

Pyricularia oryzae, the causal agent of rice blast disease, is a serious threat to rice. It reduces the yield and quality of rice. Agrofungicide used to control rice blast is harming the environment and human health. Safer alternative is needed. This study aimed to investigate the antifungal activity of zinc oxide nanoparticles (ZnO NPs) against *P. oryzae* of Sarawak, and its phytotoxicity towards Sarawak rice. Solvothermal synthesis method was used to synthesize two sizes of ZnO NPs (~20 nm and ~40 nm). ZnO NPs showed inhibition effect on *P. oryzae* tested and the effect was isolate dependent. The effect increased along with the concentration increment of ZnO NPs. ZnO NPs were found not affecting the seed germination rate, but on the shoot and root development. The effect varies at different concentration treatments of ZnO NPs. Landrace/genotype dependent phytotoxicity effect of ZnO NPs was observed.

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KEYWORDS
Rice blast; *Pyricularia oryzae*; zinc oxide; antifungal; phytotoxicity; rice

Introduction

Rice (*Oryza sativa*) is considered as one of the most important grains. According to Shahbandeh (2022a, 2022b), the worldwide rice production in 2021/2022 was about 509.87 million metric tons, less than the total rice consumption worldwide in 2021/2022 which was about 510.29 million metric tons.

Rice yield is greatly threatened by rice blast disease caused by *Pyricularia oryzae*. It can cause yield loss of up to 50% in Malaysia (Elixon et al., 2017). Currently, this disease is prevented or controlled by

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using agrofungicide and resistant rice varieties. However, the application of agrofungicide has adverse effects, such as chemical contamination in crop products, contamination of soils and ground water, and development of new fungal strain resistant to fungicide (Wightwick et al., 2010; Davies et al., 2021). Therefore, searching for a safer alternative is very important, such as using nanomaterials.

In agriculture, nanotechnology has been greatly studied over the past decades (Zhang et al., 2021). Nanotechnology in agriculture could be promising for treating crop diseases (Rosa-Garcia et al., 2018). Several nanomaterials had been reported to have antifungal properties such as silver (Kim et al., 2012), copper (Kanhed et al., 2014), zinc oxide (He et al., 2011; Rosa-Garcia et al., 2018), magnesium oxide (Rosa-Garcia et al., 2018), and chitosan (Oh et al., 2019). The unique physical and chemical properties of the nanoparticles (NPs) make them good fungicide candidates (Rosa-Garcia et al., 2018). In this study, zinc oxide nanoparticles (ZnO NPs) were tested against *P. oryzae* isolated from rice fields in Sarawak, Malaysia.

Zinc is an essential micronutrient and plays an important role in plant metabolism (Rudani et al., 2018). It can confer beneficial effects on plants such as promotion of early flowering, increase chlorophyll content, stem and root growth (Srivastav et al., 2021). ZnO NPs can be synthesized through chemical synthesis or plant-derived synthesis by different methods (Ahmad et al., 2020; Droepenu et al., 2022). It has the potential to act as nanofertilizer at optimum concentration for crops (Azam et al., 2022). However, NPs with their ultra-small size, specific shape and unique properties can cause toxicity to plants (Parthasarathi, 2011; Lin & Xing, 2008; Boonyanitipong et al., 2011; Song & Lee, 2016; Wang et al., 2015; Chen et al., 2018). For example, ZnO NPs with a concentration of 100 µg/mL can stunt the growth and development of rice root (Boonyanitipong et al., 2011). This study aimed to study the phytotoxicity of ZnO NPs on Sarawak rice.

Materials and methods

Synthesis of ZnO NPs

The synthesis of ZnO NPs followed the procedure of Shamhari et al. (2018). First, zinc acetate dihydrate [$Zn(CH_3COO)_2 . 2H_2O$] (1.48 g) was dissolved in absolute ethanol (63 mL) in a Schott bottle and heated under 60 °C with constant stirring. Potassium hydroxide (KOH) (0.74 g) was dissolved separately in absolute ethanol (33 mL) under the same condition as $Zn(CH_3COO)_2 . 2H_2O$. KOH was mixed into $Zn(CH_3COO)_2 . 2H_2O$ by slow dripping and the mixture was heated under 60 °C with