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Research paper

A palgorskite-based nanocomposite effectively reducing the incidence of powdery mildew

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ABSTRACT

Wheat powdery mildew (PM) is one of the world's top 10 most destructive fungal plant pathogen and the routine control of this disease is by application of fungicides and disease-resistant cultivars. In this study, a nanocomposite composed of amino silicon oil (ASO) and palygorskite (Pal) was developed and can effectively inhibit the pathogen. The results demonstrated that the morphology and microstructure of Pal could be effectively modified by ASO via hydrogen bonds between $-NH_2$ of ASO and − OH of Pal, resulting in an increase of hydrophobic surface groups. Further analysis showed that nanonetworks were formed by Pal-ASO interaction, which could effectively segregate *Blumeria graminis* f. sp. *tritici* (*Bgt*) conidia from wheat leaf surface and reduce the disease index by 98%. This work provides an economic and environmentally friendly approach to control the wheat powdery mildew disease.

1. Introduction

Wheat powdery mildew, which was caused by the obligately biotrophic pathogen *Blumeria graminis* f. sp. *tritici* (*Bgt*), is one of the world's top 10 most destructive fungal plant pathogen (Dean et al., 2012). This disease can give rise to yield losses ranging from 13% to 30%. The disease incidence could be more severe (up to 50%) when PM occurred earlier than usual (Griffey et al., 1993).

Recently, the pre-penetration processes of *Bgt* conidia have been clarified, which initiate with airborne conidia landing on the wheat leaves. Subsequently, approximately one hour after the first contact with leaves, the *Bgt* conidium germinates and forms a primary germ tube (PGT), the function of which was to ensure the conidium lands on the right host surface (Ringelmann et al., 2009). A few hours later, a secondary germ tube is formed, then the tube elongates and differentiates into a swollen appressorial germ tube (AGT), which grows into lobed and septated germ tube with a short, penetration peg to penetrate the host cuticle and epidermal cell wall (Edwards, 2002; Yamaoka et al., 2006). All of the pre-penetration processes will last 12–15 h in total after inoculation (Zhang et al., 2005).

It has been reported that the pre-penetration processes of *Bgt* conidia were triggered by the wheat cuticular waxes (Carver et al., 1990; Hansjakob et al., 2010, 2011, 2012; Tsuba et al., 2002; Weis et al., 2014; Zabka et al., 2008; Zhu et al., 2017). The very-long-chain aldehydes, which were the main effective constituents of the cuticular waxes, can significantly promote the germination and differentiation of barley and wheat powdery mildew conidia in a dose- and chain-length dependent manner (Hansjakob et al., 2010, 2011, 2012). In addition, some researches indicated that other physical property factors, such as surface hydrophobicity and atmospheric humidity also played important roles in conidia pre-penetration processes (Carver et al., 1990; Ringelmann et al., 2009; Zabka et al., 2008). The present study also showed that there was a close correlation between surface hydrophobicity and the *Bgt* pre-penetration efficiency. The reduction of surface hydrophobicity resulted in a significant inhibition of *Bgt* conidia germination and differentiation on the planar artificial surfaces (Zabka et al., 2008). Additionally, the presence of free water also strongly inhibited the conidial germination and differentiation (Iwamoto et al., 2002; Manners and Hossain, 1963; Sivapalan, 1994).

Currently, the application of fungicides and plantation of the disease-resistant cultivars are two main strategies in PM disease control. However, the evolution of *Bgt* made them able to overcome host resistance and resist fungicide so that these control measures need to be continually revised, updated and developed (Dean et al., 2012).

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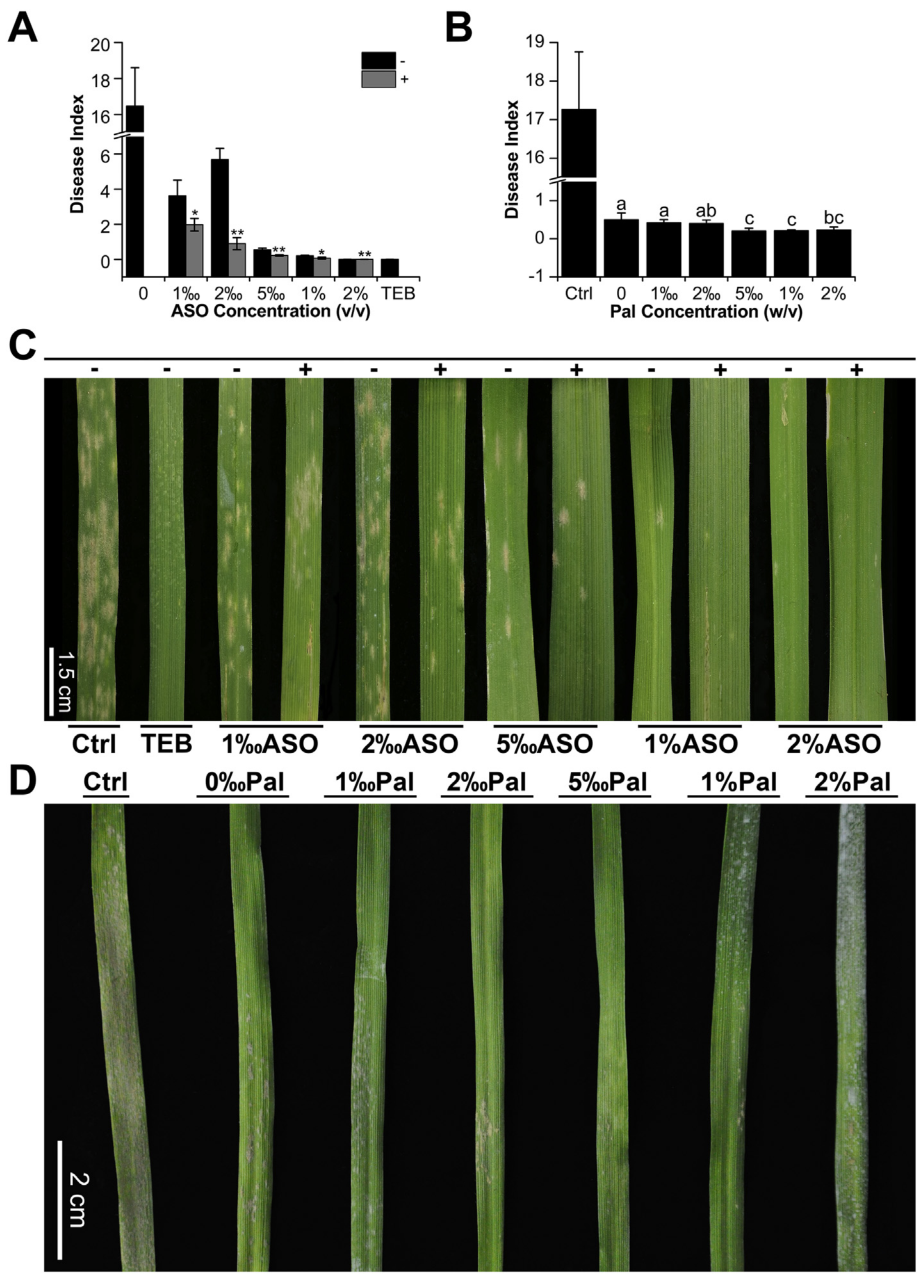

Fig. 1. Pal-ASO composite treatment confers the resistance of wheat to powdery mildew disease. (A) Disease index at 14 d post inoculation. The concentration of Pal was 5‰ (*w/v*). TEB means tebuconazole (1‰, *v*/v). Values are the mean ± s.d. of three independent experiments. "+" and "-" indicated adding Pal or not, respectively. $^{*}P < .05$, $^{**}P < .01$ (*t*-test.). (B) Disease index of *Bgt* 14 d post inoculation. The concentration of ASO is 5‰ (*v*/v). Values are the mean ± s.d. of three independent experiments. Different letters indicate significant differences, a significant difference between different treatment according to the Duncan multiple range test. (C) and (D) Macroscopic infection phenotypes of representative leaves of A and B, respectively.

Moreover, most fungicides were not environmentally friendly. Thus, it is necessary to develop a novel approach based on the feature of pre-penetration processes of *Bgt* conidia, such as using a nanocomposite to inhibit the pre-penetration processes of the *Bgt* conidia on the wheat leaf surface.

In the present study, palygorskite (Pal, (Mg, Al)$_4$(Si)$_8$(O, OH, H$_2$O)$_{26}$·nH$_2$O), which was modified by amino silicon oil (ASO), was used to form nanonetworks and applied on the wheat leaves. Pal, a kind of natural nano clay with plenty of hydroxyl groups on the surface, has high adsorption capacity and large specific surface area, thus it has been widely used in environmental remediation and agriculture (Cai et al., 2013, 2014; Chen and Wang, 2007; Frost et al., 2010; Huang et al., 2007; Shi et al., 2013; Xiang et al., 2014). Moreover, it has been reported that ASO can modify the microstructure of Pal through H-bonds to increase the hydrophobicity of Pal (Zhou et al., 2016). Generally, compared with traditional fungicides, the Pal-ASO (CAA) composite is more environmentally friendly and our study have proven the application of CAA on the wheat seedlings can effectively control the PM disease. In summary, the dominant aim of the present study was to provide an environment friendly and economic approach to fabricate a high-performance nanocomposite which can isolate the *Bgt* spores from the wheat leaf surface, and thus control the wheat powdery mildew disease. Additionally, the mechanism was also elucidated on how CAA control the PM disease in the wheat seedlings.

2. Materials and methods

2.1. Materials

The Pal powder was purchased from Anbang Co., Ltd. (Minguang, Anhui, China). Amino silicone oil (ASO) was purchased from Silok Chemical Company (Guangzhou, China). Other chemicals used in this study were analytical reagent grade and purchased from Sinopharm Chemical Reagent Company (Shanghai, China).

Spring wheat line 'Yangmai158' which was susceptible to PM, was used in this work. Seeds of 'Yangmai158' were planted in the glass tubes