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# Inter-seasonal and altitudinal inoculum dynamics for wheat stripe rust and powdery mildew epidemics in Gangu, Northwestern China

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ABSTRACT

Inter-seasonal and altitudinal dynamics of airborne spores of wheat stripe rust and powdery mildew pathogens were studied in northwestern China (Gangu, Gansu) in this study. Burkard spore traps were placed in three locations of Gansu county of the Gansu province at various altitudes, named South mountain, Valley and North mountain. Airborne spore samples were collected from March 2013 to December 2015, totaling 1365 collections for each pathogen. The airborne spore concentration of both pathogen, quantified using duplex real-time PCR assay, were consistently higher in the spring and summer than in fall and winter seasons. The within-crop season airborne inoculum levels were associated with disease severity levels. No difference was found in the Area Under the Spore Concentration Progress Curve (AUSCPC) between spring and summer for both pathogens as well as among the three locations, and there was significant correlation of ten-day spore concentrations between any two of the three locations. Our findings suggest that Gangu is an important source of oversummering inoculum for both diseases with frequent exchange of airborne spores within this region. The time-series analysis demonstrated that the airborne spore concentrations of *Pst* for all the 10-day-spore-sum during 3 years at three locations were all significantly described by the Autoregressive Integrated Moving-Average (ARIMA) (1, 0, 0) models, while, those of *Bgt* fitted different models, which contributed to predicting the tendency of airborne spore concentrations for both pathogens in Gangu.

## 1. Introduction

Stripe rust, caused by *Puccinia striiformis* Westend. f. sp. *tritici* Eriks. (*Pst*), is a devastating foliar disease of wheat worldwide (Chen, 2005; Chen et al., 2014), particularly in China, given the large extension of epidemics resulting in significant yield loss (Wan et al., 2004, 2007; Zeng and Luo, 2006). In China, epidemics depend extensively on pathogen migration and long-distance dispersal (Zeng and Luo, 2006). Thus, sources of initial inoculum for epidemics can be either exogenous or endogenous depending on ecological features, and knowledge about potential sources and timing of inoculum release are important to design regional disease management strategies. Although the sexual stage of *Pst* had been proved to occur naturally (Zhao et al., 2013), urediniospores seem to play a critical role in stripe rust epidemics in China (Chen et al., 2014). Northwestern regions of China were considered as main sources of initial inoculum for early season epidemics in eastern China due the ability of *Pst* to oversummer (Li and Zeng, 2002).

Tianshui is located in mountainous area of Gansu Province at the altitude ranging from 800 m to 2400 m above sea level (asl). The topographic and climatic diversity and distribution of various wheat cultivation systems from low to high altitudes in this area favor inoculum survival and epidemic development (Li and Zeng, 2002; Zhang and Li, 1991). Gangu County of Tianshui has been considered as the most important location, providing significant amount of inoculum to initiate nationwide stripe rust epidemics (Zeng and Luo, 2006). Wheat-growing seasons during winter and spring overlap among different altitudes and volunteer plants can be found at different periods of time, thus serving as a bridge for the pathogen to cross summer and infect plants during the fall at other locations (Zeng and Luo, 2006). Vertical (altitudinal) dispersal of spores is assumed to occur and potentially play an important role in pathogen oversummering and overwintering due to cool summer at high altitude and mild winter at low altitude. However, direct evidence of the year-round presence of airborne spore across different altitudes is lacking and the knowledge could lead to improved understanding of the aerobiology and risk of epidemic onset at different time periods.

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Powdery mildew, caused by *Blumeria graminis* (DC.) Speer f. sp. *tritici* Marchal. (*Bgt*), is increasing in importance for wheat crops in China due to significant yield loss (Cao et al., 2016; Zeng et al., 2010). Since 2001, the disease occurred in 6–8 million hectares of wheat in China (Zheng et al., 2013). Furthermore, the pathogen is capable of long distance dispersal (Limpert et al., 1999) and it has been found to complete its life cycle in Gangu (Li et al., 2013), potentially serving as initial source of inoculum for epidemics on seedlings during the fall season. Previous studies showed that the ability of powdery mildew pathogen to overwinter in diseased leaves or wheat debris in most wheat-growing regions in China (Liu and Shao, 1998), but its ability to oversummer in western regions, build up inoculum during the summer period and disperse long-distance are still unclear. Although both conidia and ascospores of *Bgt* both could serve as initial inoculum, the conidia played a much more prominent role than ascospores did on disease development (Cao et al., 2011; Liu and Tang, 1985; Zheng et al., 2013).

Therefore, knowledge of the inter-seasonal inoculum dynamics of both *Pst* and *Bgt* in this region is needed. For instance, the questions about year-round airborne spore dynamics and the possible relationship of spore dynamics among different altitudes in this region still need answers. Importantly, we still didn't know the possible amount of airborne spores out of the wheat-growing season in summer. We also had no clue about the possible existence, as well as the amount, of the inoculum during the winter in this region.

Using spore traps to monitor airborne inoculum and to answer above questions is an applicable approach in epidemiological research. Burkard spore trap (Aylor, 1993; Kennedy and Wakeham, 2015) is an efficient tool to collect airborne spores. However, the traditional approach to quantify spore concentration by microscopic counting is time consuming and labor intensive. Real-time quantitative PCR (*q*PCR) approach had been widely used in epidemiological studies to quantify plant pathogen spores and to predict plant disease developments (Luo et al., 2007; Meitz-Hopkins et al., 2014; West and Kimber, 2015), including wheat stripe rust (Dedeurwaerder et al., 2011) and powdery mildew (Cao et al., 2016). Duplex quantitative PCR allows simultaneous quantification of two different targets (pathogens) (Bernal-martínez et al., 2012; Yang et al., 2015).

The objectives of this study were to (i) monitor the intra and inter-seasonal fluctuation patterns of airborne spore concentrations of *Pst* and *Bgt*, (ii) analyze the relationship between the Area Under the Spore Concentration Progress Curve (AUSCPC) and the Area Under the Disease Progress Curve (AUDPC) of disease index recorded at different developmental stages, and (iii) compare spore concentrations at three altitudes.

## 2. Materials and methods

### 2.1. Study area

The Weihe River crosses Gangu County from west to east, and splits this mountainous area into three parts: South mountain, Valley and North mountain. Air humidity generally decreases from south to north, and temperature declines with increasing of altitude. In this study, three representative locations were selected and spore traps were placed at three altitudes (Fig. 1): 1730 m asl at South mountain

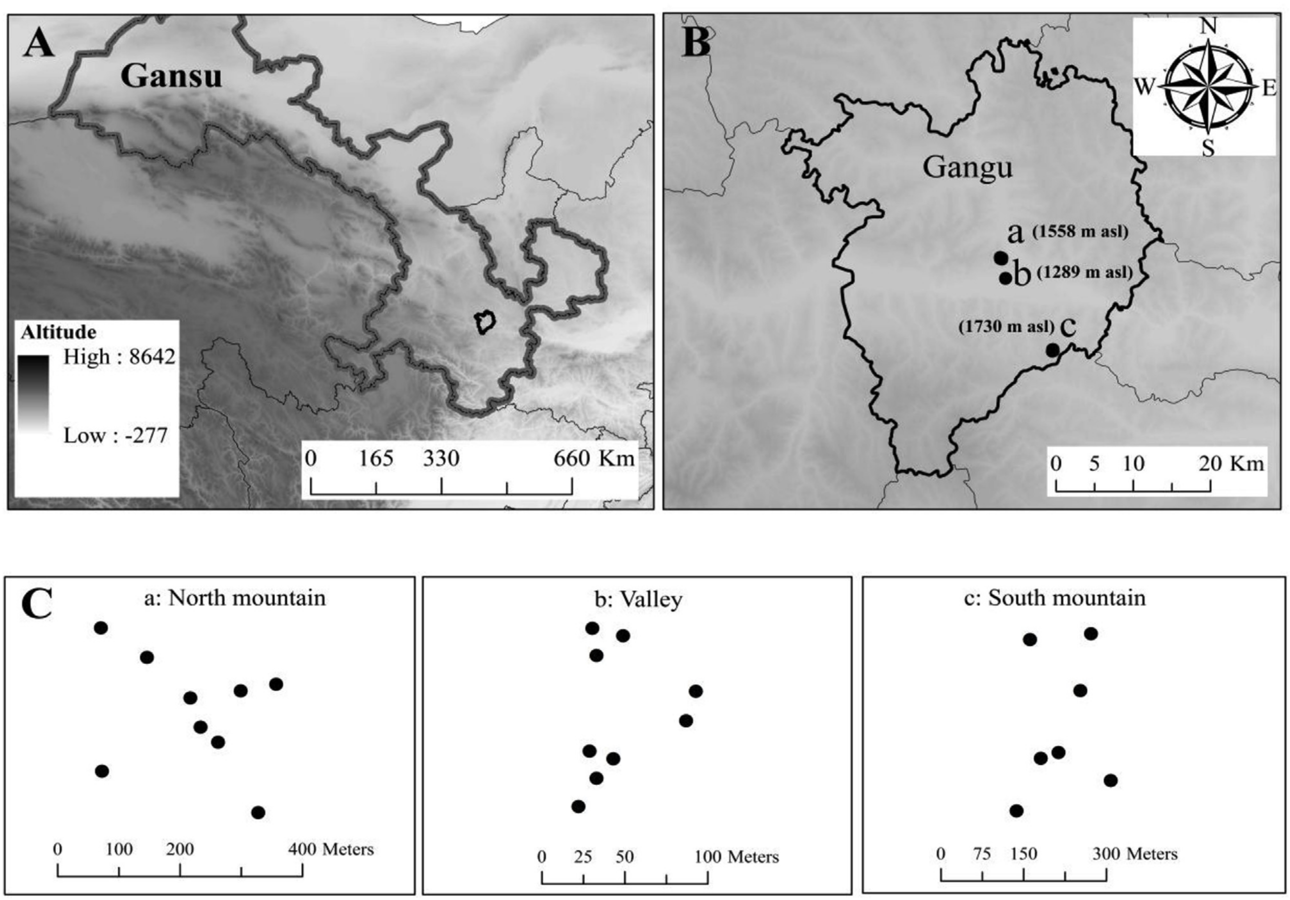


**Fig. 1.** The locations where the spore traps were placed and the wheat fields for disease assessment of stripe rust and powdery mildew used in this study. A: Map showing the location of Gangu county within Gansu province and the topology of the surrounding area. B: Three locations in Gangu county where spore traps were placed: a: North mountain, b: Valley, and c: South mountain. C: Distribution of the wheat fields used for disease assessment of stripe rust and powdery mildew at three locations involved in this study. Each dot represents a wheat field with about 200–600 $m^2$.