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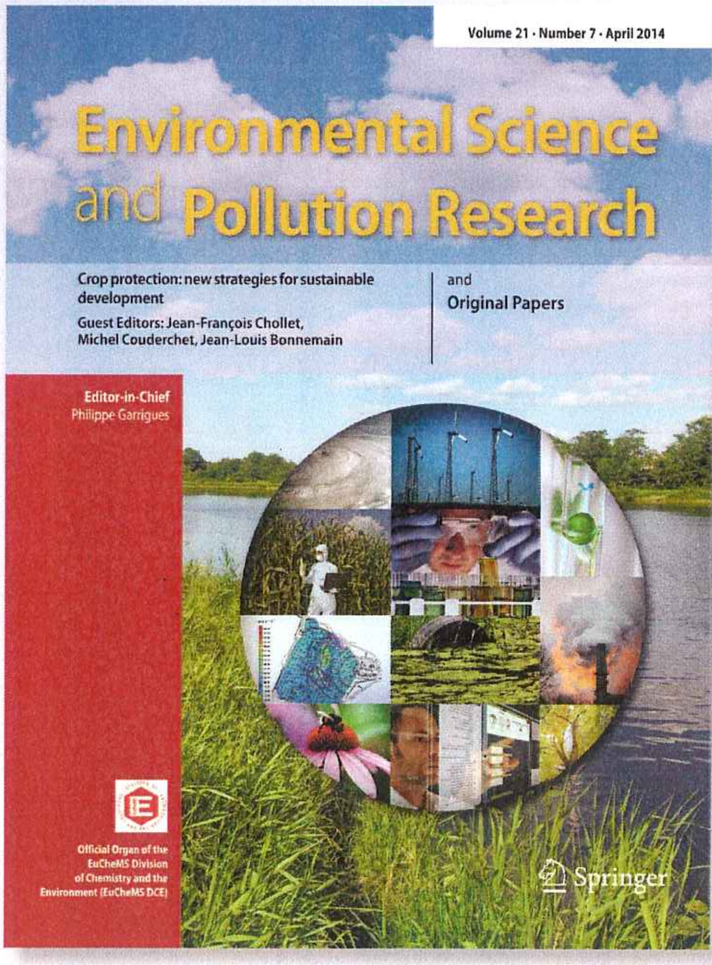

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CROP PROTECTION: NEW STRATEGIES FOR SUSTAINABLE DEVELOPMENT

Brown rust disease control in winter wheat: I. Exploring an approach for disease progression based on night weather conditions

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Abstract An empirical approach for simulating the infection and progress of leaf rust (caused by *Puccinia triticina*) during stem elongation on winter wheat was analysed for the 2000 to 2006 growing seasons. The approach was elaborated based on night weather conditions (i.e., air temperature, relative humidity and rainfall) and leaf rust occurrences. Data from three consecutive cropping seasons (2000–2002) at four representative sites of the Grand-Duchy of Luxembourg were used in the set-up phase. The capability to correctly simulate the occurrence expression of *P. triticina* infections on the upper leaf layers was then assessed over the 2003–2006 period. Our study revealed that the development of leaf rust required a period of at least 12 consecutive hours with air temperatures ranging between 8 and 16 °C, a relative humidity greater than 60 % (optimal values being 12–16 °C and up to 80 % for air temperatures and relative humidity, respectively) and rainfall less than 1 mm. Moreover, leaf rust occurrences and infections were satisfactorily simulated. The false alarm ratio was ranged from 0.06 to 0.20 in all the study sites. The probability of detection and critical success index for WLR infection were also close to 1 (perfect score).

Keywords Night weather · Disease occurrence · Disease severity · *Puccinia triticina* · Leaf rust

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Introduction

Wheat (*Triticum aestivum* L.) is one of the three main cereal crops with over 600 million tonnes being harvested annually (Shewry 2009). For example, in 2011, the total world harvest was about 701 million tonnes compared with 885 million tonnes of maize and 722 million tonnes of rice (http://faostat.fao.org/). However, its production is highly constrained by several fungal diseases including rusts (Marasas et al. 2004). Wheat leaf rust (WLR) caused by *Puccinia triticina* Eriks is of a major historical and economic importance worldwide, and the most widespread of the three types of rusts causing significant yield losses over large geographical areas (Saari and Prescott 1985; Samborski 1985; Roelfs et al. 1992; Rossi et al. 1996; Kolmer 2005; Bancal et al. 2007).

Several studies in extensive cereal-producing areas have revealed that WLR epidemics occur under (1) favourable conditions for overwintering spores as a source of primary inoculum, (2) rapid and abundant production of wind-dispersed urediniospores, and (3) a complex interaction between environmental conditions and host resistance (Eversmeyer and Kramer 2000; Bancal et al. 2007). Defining the influence of exogenous factors on the germination of urediniospores and subsequent development of infection structures is essential to our understanding of WLR epiphytotics. Air temperature, duration of surface wetness and light can have a pronounced influence on the development of infection structures. Delay or inhibition of germination of *P. triticina* urediniospores by light intensity has been reported by several studies (Chang et al. 1973; Eversmeyer et al. 1988). The presence of free water on the leaf surface is also essential for uredospore germination and light inhibits. Infections occur, therefore, preferentially at night (Eversmeyer et al. 1988). Moreover, epidemiologically, the source of moisture is important in that temperatures favourable for dew during a clear, calm night are likely to be lower than on a cloudy night. Leaf wetness and air temperature are the limiting factors under field conditions. De Vallavieille-Pope et al. (1995) showed that optimum temperatures for uredospore germination were ranged from 12 to 15 °C and the germination process was stopped above 35 °C. They also reported that the pathogens were less affected by a dry period after a short wetness period at low temperatures than at high temperatures because the germination was slow at low temperatures. In addition, leaf temperatures below the ambient air temperature may not be optimum for spore germination and infection (Eversmeyer et al. 1988). This author also noted that the latency period was about 8 to 20 days for air temperatures ranging from 10 to 20 °C; but it can be reduced to 6 days with air temperatures of 20 °C the day and 10 °C the night for susceptible varieties.

The rain has different and antagonistic effects of the epidemic in function of the type of rain. Most rainfall events promote spore dispersal produced in the field but harm the plant contamination by these spores. Two types of rainfall (i.e., "disruptive" and "enhancers") were described by Sache (2000). These events may multiply the concentration of spores in the air by a factor of 2 to 5. Disruptive rains cause the suppression of spore production for a period equal to or greater than 6 h because they deplete the lesions.

As climate changes and unpredictable weather conditions become the norm, concern on the effect on disease management is not following suit (Coakley et al. 1999). In the Grand-Duchy (GDL) WLR provides an excellent example of a disease that likely has become a nuisance due to changing weather conditions, as the latest epidemics are probably not the product of a recent introduction, but the result of weather instability (El Jarroudi et al. 2012). Assessing disease infection is of utmost importance since it is a key variable for optimising fungicide spraying time in early warning systems (Moreau and Maraite 1999, 2000). Existing forecasting systems (Buchenau 1970; Eversmeyer and Burleigh 1970; Burleigh et al. 1972; De Vallavieille-Pope et al. 1995; Eversmeyer and Kramer 2000; Audsley et al. 2005) developed to provide guidelines for efficient use of fungicides in winter wheat are based on the weather conditions throughout the day. As part of a study focusing on the brown rust disease control in winter wheat, this paper aims at assessing the range of night weather conditions (i.e., air temperature, wet period, rainfall) which favour the infection of WLR in winter wheat in the GDL.

Materials and methods

Study sites

Four Luxembourgish locations (Burmerange [49°29′N, 6°19′E], Christnach [49°47′N, 6°16′E], Everlange [49°46′N, 5°57′E] and Reuler [50°03′N, 6°02′E]) were selected to carry out field experiments over the 2000–2006 cropping seasons. Crop management data for these experiments are given in Table 1. Experimental fields were typically sown around mid-October. The sowing and harvest methods and crop practices used reflected the usual wheat production practices in the GDL. In each location and for each cropping season, the winter wheat cultivars were sown in a randomised block design with four replicates (control and fungicide treated plots; replicate plot size of 8.0×1.5 m. They included susceptible, semi-susceptible and weakly susceptible cultivars (BSA 2008)). The range of genotypes differing in rust susceptibility was unequally distributed among years and sites (Table 1). Rust susceptibility was ranged from 3 to 8 (1 referring to a low susceptibility).

Detailed experimental method could be found in El Jarroudi et al. (2009). Throughout the paper, reference will be made to the specific leaf positions on the wheat stem. These leaves are numbered relative to the uppermost flag leaf, or L1 (for leaf 1), with the leaf immediately below designated as L2, followed by L3 and so on (Shaner and Buechley 1995). Only control plots were involved in this study. Plant growth stages (GS) were assessed according to a decimal scale (Zadoks et al. 1974).

Disease monitoring

Visual assessments of the WLR severity (% of total leaf area covered by the disease symptom) of the top three leaves were achieved between GS 31 and GS 85. For a given cropping season, the disease severity on each plot was recorded by the same rater in the same field. Before the experiments, raters were trained in visual assessment using the computerised disease assessment software Distrain (Tomerlin and Howell 1988) and standard area diagrams for cereal diseases (James 1971). Ten plants per plot were marked at the beginning of disease assessment and monitored weekly along the growth season (from mid-April to early July). Note that over the study period, several fungal diseases were also involved (i.e., *Septoria* leaf blotch, wheat powdery mildew and *Fusarium* head blight).