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Interactions between crop biomass and development of foliar diseases in winter wheat and the potential to graduate the fungicide dose according to crop biomass

Peter Kryger Jensen*, Lise Nistrup Jørgensen

Aarhus University, Science and Technology, Department of Agroecology, AU-Flakkebjerg, DK-4200 Slagelse, Denmark

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ABSTRACT

Foliar pathogens such as *Zymoseptoria tritici* and *Puccinia striiformis* causing septoria leaf blotch and yellow rust respectively can cause serious yield reduction in winter wheat production, and control of the diseases often requires several fungicide applications during the growing season. Control is typically carried out using a constant fungicide dose in the entire field although there may be large differences in crop development and biomass across the field. The objective of the study reported in this paper was to test whether the fungicide dose response curve controlling septoria leaf blotch and other foliar diseases in winter wheat was dependent on crop development and biomass level. If such a biomass dependent dose response was found it was further the purpose to evaluate the potential to optimize fungicide inputs in winter wheat crops applying a site-specific crop density dependent fungicide dose. The study was carried out investigating fungicide dose response controlling foliar diseases in winter wheat at three biomass densities obtained growing the crop at three nitrogen levels and using variable seed rates. Further the field experiments included three fungicide dose rates at each biomass level, an untreated control, and 75%, 50% and 33% of the recommended fungicide dose rate and the experiments were replicated for three years. Crop biomass had a significant influence on occurrence of septoria and yellow rust with greater disease severity at increasing crop biomass. In two of three years, the interaction of crop biomass and fungicide dose rate had a significant influence on disease severity indicating a biomass-dependent dose response. The interaction occurred in the two years with high yield potential in combination with severe disease attack. If the variation in crop density and biomass level obtained in the study is representative of the variation found cultivating winter wheat in heterogeneous fields, then there seems to be scope for optimizing fungicide input against foliar diseases site-specific adapting the dose according to crop density/biomass.

1. Introduction

The control of leaf diseases in arable crops is usually performed using a constant fungicide dose in the entire field based on an assessment of which diseases are present, disease incidence and weather forecasts in the field or using regional disease data as a whole (www.Registreringsnet.dk). However, there may be large differences in crop development in different parts of a field typically related to differences in soil type and furthermore there may be differences in disease severity in the individual field related to soil type as well as topography, windbreaks, etc. (Bjerre et al., 1998, 2006). Analyses of yield gains from fungicide control have shown a tendency for higher yield increases at sites with high yield potential (Paveley et al., 1996; Oerke and Dehne, 1997; Dansk Landbrugsrådgivning, 2003). A site-specific fungicide application potentially offers several advantages, including better overall yield response to applied fungicides, and site-specific disease control further complies with the objectives in Integrated Pest Management (Anon, 2006), stating that cropping factors should be manipulated in order to limit the need for fungicides (Jørgensen et al., 2014). From an environmental point biomass-adjusted fungicide application has the advantage that the amount of fungicide deposited on the soil surface is reduced (Jensen and Spliid, 2003a, 2003b) and consequently the leaching potential is reduced.

* Corresponding author.
E-mail address: PKJ@agro.au.dk (P.K. Jensen).

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Site-specific disease control in arable crops has not received the same attention as site-specific weed control. This may be due to the fact that site-specific weed control has a larger pesticide reduction potential but also that effective control of many diseases often should be carried out very early in the infection cycle at a time when the disease is difficult to detect with existing methods (Burke and Dunne, 2008; van den Berg et al., 2013; Paveley et al., 1996). Research efforts in site-specific disease control has so far primarily focused on remote sensing of diseases (Franke and Menz, 2007; Huang et al., 2007; Moshou et al., 2011). The aim of the study reported in this paper was to investigate whether the applied fungicide dose should be varied according to crop density/biomass in order to apply a constant fungicide dose rate per leaf area index or crop biomass. A similar approach was investigated by Fournier et al. (2013), who built a model to optimize the use of fungicides particularly for control of septoria tritici blotch (STB). The theory was also tested in potatoes (Jensen and Nielsen, 2015) and winter wheat, the two crops with the largest consumption of fungicides in Denmark (Anon, 2014). This paper reports on the study in winter wheat. Crop biomass was varied by applying different nitrogen levels and seed rates. Differences in available soil nitrogen are one of the factors responsible for differences in biomass across heterogeneous fields, and nitrogen supply is known to result in enhanced growth producing a denser crop with a larger leaf area index (Hansen and Schjoerring, 2003). Nitrogen supply has been found to enhance epidemic development of some of the main fungal diseases in winter wheat such as powdery mildew (*Blumeria graminis* (DC.) Speer) (Olesen et al., 2003b; Loyce et al., 2008), yellow rust (*Puccinia striiformis* f.sp. *tritici* West) (Danial and Parlevliet, 1995; Neumann et al., 2004) and leaf rust (*Puccinia recondita* Rob & Desm.) (Cox et al., 1989; Mascagni et al., 1997; Brinkman et al., 2014). Semi-biotrophic pathogens such as *Zymoseptoria tritici* (Desm.) Quaedvlieg and Crous causing septoria leaf blotch (STB) have also been found to increase with increasing nitrogen availability (Howard et al., 1994; Leitch and Jenkins, 1995; Lovell et al., 1997) although climatic conditions, especially rainfall events, are considered of main importance for the development of this disease (Lovell et al., 1997). With several important foliar diseases, and as a consequence a large input of fungicides, winter wheat was chosen as a crop where the theory whether the applied fungicide dose should be varied according to crop density and biomass in order to obtain the same efficacy on diseases independent of crop density was tested.

2. Materials and methods

Field experiments were carried out at the Department of Agroecology in Flakkebjerg from 2012 to 2014. Flakkebjerg is located at 55°19′N, 11°24′E. Three experiments were carried out in winter wheat on a sandy clay loam. A total of 12 experimental treatments were included in each experiment. To achieve differences in crop development and biomass representative of the variation that could be expected in winter wheat crops grown in fields with varying soil type, sowing rate and nitrogen level were varied. Three levels of crop density/biomass were aimed at applying three combinations of sowing rate and nitrogen rate (1,Low: 250 kernels/m^2, 80 kg N/ha, 2,Medium: 325 kernels/m^2, 160 kg N/ha, and 3,High: 400 kernels/m^2, 240 kg N/ha). The low nitrogen rate of 80 kg N/ha was applied at a single timing whereas 160 and 240 kg N/ha were applied in two applications at approximately a 4-week interval. In the results section the three combinations of nitrogen/seed rate are referred to as low, medium and high.

Due to poor over-wintering of the first established experiment it was moved to another winter wheat crop and only nitrogen rate was varied in 2012. Also, the variety was Baltimor in 2012 and Hereford in 2013 and 2014. The 3 levels of crop density/biomass were combined with 4 levels of fungicide dose: an untreated control and 3 rates of boscalid + epoxiconazole (Bell, containing 233 g a.i. of boscalid/l + 67 g a.i. epoxiconazole/l, BASF A/S, Denmark). The fungicide was applied at a dose rate of 1.13 l/ha, 0.75 l/ha and 0.5 l/ha corresponding to 75%, 50% and 33% of the recommended dose rate. Fungicide application was carried out with a self-propelled plot sprayer equipped with Hardi LD-110-015 pre-orifice nozzles at 250 kPa delivering a volume rate of 150 l/ha at 4.5 km/h. Nozzle spacing was 500 mm and boom height 500 mm above crop. The spray quality is medium according to the BCPC classification system (Southcombe et al., 1997). Except from the experimental treatments described, the crop was grown according to normal agricultural practice at a row distance of 125 mm. During periods with precipitation deficit, experiments received irrigation. All three experiments included 4 replicates in a randomized block design and the plot size used was 10 m × 2.5 m. The fungicide treatments were planned around heading (BBCH 49-51). The actual application dates and other background information are shown in Table 1.

Foliar disease severity was evaluated at 10-day intervals following the fungicide application with assessments of percent leaf area covered by disease according to EPPO guideline PP 1/26 (Anon, 2008). In 2012, both STB and yellow rust were present and assessed in the trials, whereas in 2013 and 2014 STB was the major disease. Crop development was evaluated by two methods; development was assessed making LAI measurements using a Licor LAI 2200 Plant Canopy Analyzer measuring canopy light interception and by calculating a vegetation index (Jensen and Christensen, 1993) from reflectance measurements with a Cropscan CT100 in the red and infrared spectrums. Both measurements were carried out in the period around fungicide application to characterize crop development/biomass.

Deposition of spray liquid on plant sections was measured at the same growth stage as when the experimental fungicide application was carried out. A tracer, brillantsulfoflavin, was added to the spray liquid at a dose of 100 g/ha in 150 l/ha spray volume and applied to the plots together with the low dose rate of Bell. This means that deposition was measured in the combinations crop biomass × replicates, giving a total of 12 plots. Following the application, 10 plants from each plot were collected randomly and separated into 3 fractions, 1. 1st leaf (flag leaf), 2. 2nd leaf, and 3. 3rd leaf. The tracer was solved from the leaf samples in 50 ml demineralized water and the bottles were shaken thoroughly and a small proportion of the liquid was used for the analysis. Samples of the spray liquid were taken and stored the same way. The concentration of tracer in the liquid samples was determined using a Perkin Elmer model LS50B luminescence spectrometer. The bottles were shaken and a sample of 6 μl was used in the fluorescence detector. The sample was excited at a wavelength of 420 nm, and after excitation emission was measured at 518 nm and quantified using several standard concentrations ranging from 10 to 2000 μg l^{-1}. From the concentration of brillantsulfoflavin in the sample the actual amount of tracer on the leaf sections was calculated. For control purposes tracer concentration was also determined in the

Table 1
Details of growth stage, application date, etc. in the 3 experimental years.

	2012	2013	2014
Variety	Baltimor	Hereford	Hereford
Sowing date	13/09/2011	21/09/2012	13/09/2013
Fungicide application date	25 May	6 June	21 May
Spray deposition measurement[a]	25 May	6 June	21 May
Growth stage at application (BBCH)	45	53	47

[a] Tracer was applied together with the low fungicide dose rate.