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Cropping systems with maize and oilseed rape for energy production may reduce the risk of stem base diseases in wheat

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ABSTRACT

Cropping systems with crops cultivated in short cycles on the same land provoke phytosanitary problems which may force more chemical inputs. However, the potential effects of cropping systems with emphasis on energy crops, i.e. maize and oilseed rape on the incidence and severity of stem base and root diseases of wheat have not been investigated thoroughly. We therefore analyzed the effects of varied percentages of maize and oilseed rape on stem base and root pathogens of winter wheat grown in four different cropping systems and rotations in two locations in Central and Northeastern Germany for three years. Our results demonstrate that short and intensive crop rotations with wheat combined with crops for bioenergy production do not necessarily enhance the risk by soil and straw borne diseases. Moreover, a suitable combination of wheat, oilseed rape and maize with adapted cropping methods (late sowing after maize, ploughing) can significantly mitigate the threat of stem base diseases in wheat. While disease incidence of sharp eyespot was always <5%, cropping systems had significant effects on the incidence and severity of eyespot, fusarium foot rot and take-all (in Northeastern Germany). Incidence of fusarium foot rot and take-all was significantly reduced by 70% and incidence of eyespot nearly to 0%, when wheat was planted after maize in a system with late sowing and ploughing, compared to wheat after oilseed rape with reduced tillage and early sowing. Further, these cropping systems with maize showed a low level of fusarium head blight. DON levels in grains were always low. The present study demonstrates that current shifts in crop rotations to a higher prevalence of maize due to novel market developments do not necessarily enhance the phytosanitary risks in the main crop wheat, if a suitable system of agronomic measures is applied, enabling highly productive and sustainable energy crop production systems.

1. Introduction

The market situation and the potential to control diseases and pests with pesticides have significantly reduced the diversity of crops grown in Germany in the past 50 years. From 1990 to 2010, the percentage of arable land grown to wheat, maize and oilseed rape has increased by 38%, 46% and 100%, respectively, and in 2010, these three main crops were grown on 70% of the arable land in Germany (Federal Statistical Office, 2010). Political frameworks facilitating the production of bioenergy lead to increased cultivation of maize for biogas (650,000 ha in 2012) and of oilseed rape for biofuel production (900,000 ha in 2012). In 2012, crops for energy purposes (i.e. predominantly maize, oilseed rape and sugar beet) were grown on more than 2.1 m ha in Germany equivalent to 17% of the total arable land (FNR, 2012). Together with a general trend toward less diverse crop rotations (Karlen et al., 1994), the need for increased biomass production has shortened crop rotations. Shorter rotations may increase disease risks particularly induced by soil and straw borne pathogens. In wheat (*Triticum aestivum* L.) grown in short rotations several such fungal pathogens may be favored which infect the stem base and root (Kirkegaard et al., 2008). Diseases most responsive to crop rotation in cool-temperate zones are eyespot caused by *Oculimacula yallundae*/*O. acuformis* (Crous et al., 2003), take-all disease caused by *Gaeumannomyces graminis* (Mielke, 1998), fusarium foot rot caused mainly by *Fusarium culmorum* (Duben and Fehrmann, 1979; Clement and Parry, 1998) and sharp eyespot caused by *Rhizoctonia cerealis* E.P. van der Hoeven. Infection at the stem base with *O. yallundae/acuformis* leads in severe cases to lodging and limited water and nutrient supply of upper plant parts including the grains, which leads to significant yield losses (Glynne and Salt, 1958; Scott and Hollins, 1974; Clarkson, 1981). Severe infections with *G. graminis* can damage the roots and vascular system resulting in white heads and premature ripening (McMillan et al., 2011). Both pathogens, in the

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absence of their hosts, survive as mycelium on infected straw and stubbles on and in the soil (Hornby, 1975; Prew, 1980). *R. cerealis*, which survives as mycelium and sclerotia in the soil (Keijer, 1996; Sherwood, 1970), may cause yield losses in different wheat cultivation regions in the world (Hamada et al., 2011). Fusarium foot rot occurs in all wheat growing areas worldwide, with severe damage being reported from the Pacific Northwest (Cook, 1968; Smiley, 1996), Australia (Wildermuth et al., 1997; Smiley, 1996) and the Middle East (Fouly and Pedersen, 1996). The main causal agents are *Fusarium graminearum*, *F. pseudograminearum* and *F. culmorum* (Smiley, 1996; Cook, 1980; Clement and Parry, 1998) which are capable of rotting the stem bases and roots (Smiley, 1996). In the absence of their hosts, fusarium species predominantly survive on infected plant debris, while *F. culmorum* may form durable chlamydospores in the soil as well (Cook, 1980). Since the EU directive 2009/128/EC and the German plant protection act (Anonymus, 2012) aims at sustainable pesticide use based on integrated pest management systems, preventive strategies to control plant diseases including suitable cropping systems will become more important in the future. Our aim was to study different cropping systems with regard to stem base and root diseases of wheat. Effects of different cropping systems were due to combined effects of tillage and crop rotation. Crop rotation effects originated from different percentages and varying sequences of wheat, maize and oilseed rape. Different sequences enabled either early or late sowing of wheat, which is considered to have major effects on wheat stem base and root pathogens. There are several studies from Germany on the effects of preceding crops like oilseed rape, wheat, barley, peas and oats in different crop rotations on yield of wheat and oilseed rape and soilborne diseases like take-all (Christen and Sieling, 1995; Christen et al., 1992; Sieling et al., 2007). Studies addressing the potential and limitations of current or future cropping systems integrating maize with relation to soil and straw borne pathogens are however rare. Hence, the aim of this study was to conduct field experiments in order to explore how recently established energy cropping systems including forage rye/maize and oilseed rape affect the risk of root and stem base diseases in winter wheat. The particular approach of this study was to investigate whole cropping system effects, including crop species, crop sequences and agronomic practices associated with each crop, rather than just the effects of specific preceding crops.

2. Materials and methods

2.1. Field sites

Experiments were conducted in a field near Göttingen (latitude of 51° 33′ 25.76″ N, longitude 9° 55′ 12.84″ E) and a second one near Rostock (latitude 54° 3′ 54.39″ N, longitude 12° 4′ 47.34″ E), Germany. The site in Göttingen is located in the south of Lower Saxony at 170 m above sea level (mamsl), mean annual precipitation of 708 mm and a mean annual temperature of 9.5 °C (average from 2001 to 2010, Weather Station Göttingen, 2011). The soil type is loamy silt. The field in Rostock (Mecklenburg-Western Pomerania) is located 15 km away from the Baltic Sea coast at 45 mamsl. The mean annual temperature between 2005 and 2010 was 8.6 °C with mean annual precipitation of 697 mm (Steinbeis Transferzentrum (STZ) für Angewandte Landschaftsplanung, 2011). The soil type is loamy sand.

2.2. Field trial and cultural practices

Field trials were set up in a two-factorial split-plot design. The cropping system was included as a main factor and fungicide treatment as a subfactor in 4 replications (blocks). For agronomic reasons 2 blocks were combined to pseudo-replications. Three cropping systems with maize, oilseed rape, winter wheat and forage winter rye as a catch crop to bridge the winter before maize were established as follows: (1) oilseed rape–winter wheat (OR–WW), (2) oilseed rape–forage rye/maize–winter wheat (OR–R/M–WW) and (3) oilseed rape–winter wheat–forage rye/maize–winter wheat (OR–WW–R/M–WW). Thus, maize was planted in rotations every third or fourth year, wheat every second or third year and oilseed rape every second, third or fourth year. The different sequences of crops resulted in early or late sowing of wheat. In OR–WW–R/M–WW the combination OR–WW resulted in early sowing of wheat (mid-September after tillage with a grubber), whereas after maize wheat was sown late (mid-October after ploughing) in the same cropping system. Likewise OR–WW and OR–R/M–WW led to early (after tillage with a grubber) and late sowing (after ploughing) of wheat, respectively. In the following we consider this combined effect of sowing date, preceding crop and tillage as a sequence effect. Two different fungicide treatments were conducted. Fungicide application according to good farming practice (F) and no fungicide application (F-0). Fungicides were applied at growth stage (GS, Tottman, 1987) 31 and at GS 51/55 in wheat. At GS 31, Input® (spiroxamine + prothioconazole, Bayer CropScience, Monheim Germany) and at GS 51/55 Champion and Diamant® (boscalid + epoxiconazole and epoxiconazole + fenpropimorph, BASF SE, Ludwigshafen, Germany) were applied. Other pesticides (herbicides and insecticides) were applied according to good farming practice. The size of the plots was 6 m × 6 m in Rostock and 8 m × 7.5 m in Göttingen. Fertilizers were applied in wheat according to good farming practice. Soil nitrogen (N) was analyzed in all cropping systems after winter and N was applied to reach a final amount of 180 kg N in all cropping systems.

2.3. Sampling, disease scoring and grain yield assessment

On both locations, 25 plants with 5–8 tillers each were randomly sampled per plot at the late milk development stage (GS 77). Sampling was conducted by hand on the left and right along the harvested row (center) of each plot. Five plants were sampled at five sampling points. One hundred shoots per plot were visually assessed for stem base lesions of *Fusarium* spp. (brown, longitudinal lesions), *Rhizoctonia* sp. (sharp elliptical, eye-shaped lesions) and *Oculimacula* spp. (elliptical eye-shaped lesions) using a scale from 0 to 3 (0 = no visible lesion, 1 = lesion covering up to 50% of stem surface, 2 = lesion covering 51 to 100% of stem surface, 3 = stem base completely rotten). Roots with typical black lesions caused by *G. graminis* were scored using a scale from 0 to 4 (0 = no visible lesion, 1–10% of roots with lesions, 2 = 11–30% of roots with lesions, 3 = 31–60% of roots with lesions, 4 = 61–100% of roots with lesions). Disease severity was calculated separately for each disease according to Broschewitz et al. (1999). Grain yield was assessed with a plot combine (Farmliner, Deutz Fahr, Cologne, Germany in Göttingen and NM Elite, Wintersteiger, Ried, Austria in Rostock) harvesting a central stripe of 2.6 m × plot length in Göttingen and 1.8 m × plot length in Rostock. Grain was collected in burlap bags and plot grain yield was weighed directly on the field. Grain was dried to a final residual moisture content of 13% and purified with a sample cleaner (SLN 3, Zuther, Germany).

2.4. Quantification of deoxynivalenol in grain and stubble of wheat

After harvest, wheat stubbles were sampled following the same scheme as above, however, only main tillers were kept for further analysis (25 stubbles per plot). Roots were cut and shoots