Crop Protection 109 (2018) 102–109

Contents lists available at ScienceDirect

Crop Protection

journal homepage: www.elsevier.com/locate/cropro

In-field assessment of an arabinoxylan polymer on disease control in spring barley

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ARTICLE INFO

Keywords:
Film-forming polymer
Integrated crop management
Powdery mildew
Rhynchosporium scald
Ramularia leaf spot

ABSTRACT

With the threat of certain plant protection products becoming ineffective due to reduced pathogen sensitivity to fungicides or through the removal of products due to changes in legislation, alternative compounds are sought for use in disease management programmes. The effects of an arabinoxylan film-forming polymer derived from maize cell walls to control crop diseases of spring barley was assessed in field experiments. Control of powdery mildew, Rhynchosporium scald, and Ramularia leaf spot on barley was achieved with the polymer but control was inconsistent between trials. However, good levels of disease control were observed when the polymer was applied with a reduced fungicide programme. No yield penalties were associated with use of the polymer in any trial irrespective of the level of disease control. Alternative plant protection products such as this arabinoxylan polymer may be useful components in future integrated disease management strategies aimed at reducing fungicide inputs without any cost to disease control.

1. Introduction

Managing the levels of disease in crops is essential to maintain the high yield and quality required to feed the growing global population. Disease control is often achieved by integrating different methods including the use of specific agricultural practices to lower the risk of disease occurring combined with varietal resistance and plant protection products such as fungicides (Walters et al., 2012). Control offered by varietal resistance based on race-specific resistance genes can break down due to the emergence of newly virulent races of plant pathogens (Brown, 2015). Similarly, prolonged use of fungicides to control crop pathogens can lead to the evolution of fungicide insensitive isolates. Fungal isolates exhibiting insensitivity to fungicides have been characterised for many important crop pathogens including the major pathogens on spring barley one of the most important crops in Scotland. Isolates insensitive to different fungicide active ingredients have been reported for *Rhynchosporium commune* (Phelan et al., 2016), *Ramularia collo-cygni* (Matusinsky et al., 2011; Piotrowska et al., 2016) and *Blumeria graminis* f. sp *hordei* (Bäumler et al., 2003; Wyand and Brown, 2005), the fungal pathogens responsible for Rhynchosporium scald, Ramularia leaf spot (RLS) and powdery mildew diseases of barley, respectively. Use of fungicides to control crop diseases is also at risk from EU legislation which aims to reduce fungicide inputs and may result in the removal of important active ingredients from use in agriculture (Hillocks, 2012).

With the effectiveness of varietal resistance eroding and the risk of reduced efficacy and the potential availability of fungicides to control crop pathogens, alternative options for disease control are required. The use of compounds that elicit the plants' defence response has been shown to provide control in crops against different plant pathogens although this control can often be inconsistent and dependent on the crop variety and environment (McGrann et al., 2017; Oxley and Walters, 2012; Walters et al., 2008, 2011a; 2011b). Another alternative type of plant protection product is film-forming polymers. The waxy cuticle of the leaf surface acts as the primary barrier to pathogen invasion but also contains features that act as cues for attachment and germination of fungal spores, and for subsequent germ tube growth and pathogen invasion (Ringelmann et al., 2009; Kolattukudy et al., 1995). Applying film-forming polymers that coat the leaf surface can suppress foliar infection by pathogens and consequently provide disease control (Walters, 2006). Sutherland and Walters (2001) initially demonstrated that film-forming polymers could inhibit *in vitro* growth of *Pyrenophora avenae* and *Magnaporthe oryzae* and then reported that these polymers reduced *in planta* infection by the obligate biotroph *B. graminis* f. sp.

Abbreviations: GS, growth stage; GLM, general linear model; GzLM, generalized linear model; RLS, Ramularia leaf spot; AUDPC, area under disease progress curve

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https://doi.org/10.1016/j.cropro.2018.03.003
Received 8 December 2017; Received in revised form 6 March 2018; Accepted 10 March 2018
Available online 30 March 2018
0261-2194/

hordei on barley under controlled environment conditions and in the field (Sutherland and Walters, 2002). Percival and Boyle (2009) showed that film-forming polymers could reduce the development of *Venturia inaequalis* and the severity of scab disease on apple. However, it was noted that the control conferred by the various polymers tested was not as effective as a typical fungicide treatment. Disease control provided by film-forming polymers is usually mediated by the polymer acting as a physical barrier to penetration, interfering with the processes involved in spore adhesion, hydration and germination or by disguising the topography of the leaf surface to prevent host recognition during germ tube growth (Walters, 2006). As these compounds usually do not act directly against the pathogens, the efficacy of film-forming polymers to control crop diseases is not likely to be at risk from insensitive fungal isolates evolving that reduce the effectiveness of the polymers.

Here we report the effects of foliar application of an arabinoxylan polymer to reduce disease in field grown spring barley. Arabinoxylans are one of the main cell wall polysaccharides in cereals (Fincher, 2009) and could provide a novel, cost-effective and environmentally benign plant protection product to be used in disease management programmes to reduce reliance on fungicides for disease control in crops.

2. Materials and methods

2.1. Plant protection products

An arabinoxylan polymer, derived from maize cell walls, was obtained from Cambridge Biopolymers Ltd., Cleveland, UK. Initial studies on barley seedlings indicated that the polymer forms a film coating on the leaf surface (Rätsep et al., 2012). The polymer was applied in field trials in an unmodified form. Arabinoxylan was dissolved in deionised water to obtain a 2% w/v solution and polymerised by adding 3% hydrogen peroxide and 100 purpuroallin units of horseradish peroxidase. The polymerisation solution was mixed by shaking and incubated at 25 °C for 10 min. Following the incubation step, a firm gel was formed, which was dissolved in water and diluted to a working concentration of 0.08% arabinoxylan. The efficacy of the polymer to control disease in spring barley was tested in field trial experiments and compared against various fungicides typically used for plant protection. Details of the different fungicides used in this work are presented in Table 1.

2.2. Spring barley field trial experiments

The effect of the arabinoxylan polymer treatment on lowering disease levels on spring barley was assessed in field trials conducted at the Bush Estate, Edinburgh, Scotland, UK after Bush Estate in 2010, 2011 and 2012 and at Lanark, Scotland, UK in 2011 and 2012. Spring barley was sown in a randomised block design in plots of 10 × 2 m at a seed rate of 360 seeds m^{-2}, with a minimum of three replicates per treatment in each trial. Local standard agronomic practices were applied to each trial except for fungicide applications which are trial specific. All treatments were applied using a knapsack sprayer in a volume equivalent to 200 L ha^{-1} of water (Walters et al., 2011a).

2.2.1. Spring barley field trial at Bush Estate 2010

In 2010 the spring barley variety Optic was sown at the Bush Estate on March 6th. The polymer (0.002 L ha^{-1}) was applied as single application at growth stages (GS) GS24, GS31, GS49 and GS59 based on the scale of Zadoks et al. (1974), as a double application at GS25 and GS31 and as a triple application at GS25, GS31 and GS49 (Table 2). For each treatment three replicate plots were assessed. Disease control was evaluated by visually scoring powdery mildew (*Blumeria graminis* f. sp. *hordei*) symptoms as a proportion of leaf area covered averaged across the upper three leaf layers. Mildew symptoms were scored at GS39, GS49, GS73 and GS83 at a minimum of three points across the length of the plot. Disease score data was used to calculate the area under the disease progress curve (AUDPC; Shaner and Finney, 1977) for statistical analysis. cv. Optic has a resistance rating of 5 for powdery mildew based on the AHDB (Agricultural and Horticultural Development Board) recommended list 2011–12 (http://cereals.ahdb.org.uk/varieties.aspx). The effects of the polymer treatments on mildew control and yield were compared to a series of different fungicide treatments typical of local disease control programmes (Table 2). Plots were harvested using a research combine on September 3rd 2010. Grain from each experimental plot was collected and weighed as kg $plot^{-1}$. Moisture content was assessed on a 1 kg subsample collected from each plot which was oven dried at 103 °C for 24 h and used to standardise the yield in each plot to 85% dry matter (Walters et al., 2011c).

2.2.2. Spring barley field trials at Bush Estate 2011, 2012

At Bush Estate in 2011 and 2012 the effect of the polymer on disease control on four spring barley varieties was assessed. The varieties were selected based on disease resistance ratings against Rhynchosporium scald (*Rhynchosporium commune*): NFC Tipple (Rhynchosporium resistance rating 4), Panther (4), Quench (8), Shuffle (6). RLS resistance ratings for UK spring barley varieties were not released until 2013 and are therefore not reported as part of this study. The trials were sown on March 21st 2011 and March 15th 2012. Disease symptoms for Rhynchosporium and Ramularia leaf spot (RLS; *Ramularia collo-cygni*) were visually assessed as a proportion of leaf area covered with disease lesions averaged across the upper three leaf layers. In 2011 both diseases were first scored at a point when the GS of the four varieties varied between GS32-49. The two further score dates saw all four varieties at the same GS when scored at GS63 and GS76. Disease was scored at a minimum of three points across the length of the plot. In 2012 disease was scored at three dates corresponding to GS31, GS39 and GS72. Disease score data was used to calculate AUDPC for statistical analysis. The polymer treatment was applied at GS24, GS31 and GS49 and compared to untreated control plots and plots treated with a fungicide programme of Siltra Xpro (0.5 L ha^{-1}) at GS31 and Proline 275 (0.175 L ha^{-1}) and Bravo (0.5 L ha^{-1}) at GS49 (Table 2). Yield was calculated for each plot at 85% dry matter following harvest of the trials on August 30th 2011 and September 4th 2012 as described for the 2010 trial. Three replicate plots were assessed per treatment for each variety.

Table 1
List of fungicides used in field trial experiments.

Trade name	Active Ingredient	Company
Fandango®	100 g L^{-1} prothioconazole plus 100 g L^{-1} fluoxastrobin	Bayer CropScience, Cambridge, UK
Flexity®	300 g L^{-1} metrafenone.	BASF, Cheshire, UK
Bravo® 500	500 g L^{-1} chlorothalonil	Syngenta, Jealott's Hill, UK
Tracker®	233 g L^{-1} boscalid plus 67 g L^{-1} epoxiconazole.	BASF, Cheshire, UK
Pentangle®	500 g L^{-1} chlorothalonil plus 180 g L^{-1} tebuconazole.	Nufarm, Victoria, Australia
AmiStar® Opti	100 g L^{-1}azoxystrobin plus 500 g L^{-1} chlorothalonil	Syngenta, Jealott's Hill, UK
Proline® 275	275 g L^{-1} prothioconazole	Bayer CropScience, Cambridge, UK
Siltra® Xpro	60 g L^{-1} bixafen plus 200 g L^{-1} prothioconazole	Bayer CropScience, Cambridge, UK