Effect of organic, low-input and conventional production systems on yield and diseases in winter barley

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Abstract

The effect of organic, low-input and conventional management practices on barley yield and disease incidence was assessed in field trials over two years. Conventional fertility management (based on mineral fertiliser applications) and conventional crop protection (based on chemosynthetic pesticides) significantly increased the yield of winter barley as compared to organic fertility and crop protection regimes. Severity of leaf blotch (Rhynchosporium secalis) *was highest under organic fertility and crop protection management and was correlated inversely with yield. For mildew (*Erysiphe graminis*), an interaction between fertility management and crop protection was detected. Conventional crop protection reduced severity of the disease, only under conventional fertility management. Under organic fertility management, incidence of mildew was low and application of synthetic pesticides in "low input" production systems had no significant effect on disease severity.*

Introduction

The area farmed using organic and low-input farming practices in the UK and the rest of Europe has increased in recent years due to: incentives to adopt more environmentally sustainable practices, consumer demand, and price premiums achieved for certified organic food products (Hamm et al., 2002). While organic farmers adhere to strict standards prohibiting the use of most pesticides and mineral fertiliser sources, low-input farming encompasses a range of farming practices where the use of specific inputs is reduced or omitted (Leifert et al., 2007).

The severity of a range of disease problems (e.g. mildew, lodging) that cause economic losses in conventional wheat production was significantly reduced when crops were grown under organic management practice. However, one disease (*Septoria* spp.) was identified as the main factor limiting crop yield in wheat grown under organic management (Cooper et al., 2006). In contrast to wheat, diseases were reported to have a more limited effect on the yield of other cereals such as barley in both organic and conventional systems (Hannukkala and Tapio, 1990). The objective of the study presented here, was to compare disease incidence and severity in barley produced under both organic and conventional management, and to investigate the effect of these diseases on crop yield.

Materials and methods

A long-term experiment comparing organic (OP-OF), two low-input (OP-CF and CP-OF) and conventional (CP-CF) systems of crop production was established in 2001 at

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the University of Newcastle's Nafferton Farm, near Stocksfield, Northumberland, in the UK. The experiment is a split-split-split plot design with crop rotation as the main plot and crop protection and fertility management as the subplot and sub-subplot factors (Leifert et al., 2007). In both 2004 and 2005 winter barley of the variety "Pearl" was established following crops of winter wheat. Rainfall between crop planting and harvest was 439 mm for the 2005 crop and 340 mm for the 2006 crop.

In the CP treatment, approved herbicdes were used post-emergence in November (e.g. isoproturon, mecoprop-P, pendimethalin) and April (fluroxypyr). Approved fungicides were applied in April (picoxystrobin, prothioconazole, fenpropimorph) and May (picoxystrobin or azoxystrobin and chlorothalonil, epoxiconazole, fenpropimorph). Under conventional fertility management (CF) P and K at rates of 64 and 96 kg ha^{-1} were applied pre-plant in November and N was top-dressed in March and April at rates of 50 and 120 kg ha^{-1}. Under organic crop protection (OP) and fertility management (OF) no pesticides or fertilisers were applied.

Visual disease assessments were conducted as described in Cooper et al. (2006) on the F-3, F-2, F-1 and flag leaves on five occasions (Zadok's growth stages 49, 58-59, 65, 73, 77). Diseases assessed were powdery mildew (*Erysiphe graminis* f. sp. *hordei*), leaf blotch (*Rhynchosporium secalis*), and net blotch (*Drechslera teres* f. sp. *teres*). The final level of lodging was assessed immediately prior to harvest and was recorded as % of the crop/plot lodged.

In both years the significance of fertility management and crop protection, and the interaction between these two terms, was assessed using a linear mixed effects model in R (R Foundation for Statistical Computing, Vienna, Austria 2005), with block treated as a random effect, and crop protection as a fixed effect, nested within block (Pinheiro and Bates, 2000). Correlation analysis was used to investigate the relationships between crop yield and disease incidence/severity in each of the years. Data presented in Table 1 are all expressed as percentages of the values for the fully conventional plots.

Results

In both years the conventional crops produced the highest yields (7.6 t ha^{-1} in 2005 and 10.3 t ha^{-1} in 2006). The elimination of chemosynthetic pesticides resulted in yield reductions of 15 to 18%, while eliminating mineral NPK inputs reduced yields by approximately 40%. Under organic management yields were 49.5% and 56.9% lower than conventional in 2005 and 2006 respectively. There was no interaction between fertility management and crop protection in either year.

Lodging only occurred in 2005. Conventional management increased the lodging problem with the highest percentage recorded in the fully conventional treatment (18% of the stand). The use of mineral NPK was clearly the causative factor since treatments that were organically fertilised (CP-OF and OP-OF) had no lodging recorded at all.

In both years management practices had a significant effect on the incidence and severity of disease in barley. Only results for the flag leaf are presented here, but the

Table 1. Barley yields and diseases (as % of conventional) under different management systems, 2005 and 2006

Characteristic assessed	Year	CP-OF	OP-CF	OP-OF
Crop yield	2005	61	85	51
	2006	57	82	43
Diseases				
Lodging	2005	0	37	0
	2006	NA[1]	NA	NA
Mildew severity	2005	38	509	70
	2006	0	6694	483
Net Blotch severity	2005	6	367	111
	2006	32	3286	749
Leaf blotch severity	2005	356	343	776
	2006	47	2042	3038

[1]Not present in 2006.

same trends were observed for the other leaves studied. Mildew severity was significantly higher in management systems using mineral fertiliser based fertility management (Table 1). Fertility management interacted with crop protection ($p<0.01$ in both years) with the low input system based on conventional fertility management and organic crop protection (OP-CF) resulting in significantly higher severity of mildew than any of the other treatment combinations (Table 1). Under organic fertility management, the severity of mildew was low and there was no additional benefit gained by using conventional chemosynthetic pesticide based crop protection measures.

When compared to conventional systems, net blotch severity was highest in the low input systems using conventional fertility management and organic crop protection (OP-CF in Table 1). However, leaf blotch was significantly increased in the organically managed plots (OP-OF). There was a significant negative correlation between leaf blotch and crop yield ($p<0.0001$), but only a trend for a negative correlation in 2006 ($p=0.068$). In both 2005 and 2006, there was a positive correlation between net blotch and mildew on the flag leaf ($p=0.013$ in 2005 and 0.016 in 2006).

Discussion

The relationship between N fertilisation and the incidence of powdery mildew in the field has been well documented (Jensen and Munk, 1997). Powdery mildew is a biotrophic pathogen that thrives on succulent, N-rich, plant tissue. Cooper et al., (2006) reported that even when pesticides were used, conventionally fertilised wheat had significantly higher powdery mildew AUDPC values than organically fertilised wheat. This trend was also evident in this study on barley, which again showed that the use of pesticides for the control of mildew is not economically viable in organically fertilised crops. While both powdery mildew and net blotch were highest under conventional fertility management, correlation analysis indicated that they did not have a negative impact on crop yield with only leaf blotch severity significantly correlated with lower barley yields. While a correlation does not imply a causative relationship, other researchers have also related leaf blotch damage to losses of barley yield (Khan and D'Antuono, 1985). Leaf blotch may have accounted for some of the losses in crop yield under organic management, but a larger decline in yield can be attributed to fertility management effects (Table 1). Reduced nutrient availabilities in the organically fertilised treatments may have created stress symptoms in the crop, and increased its susceptibility to disease.

Conclusions

Declines in yield were correlated with leaf blotch severity, but larger yield losses were associated with organic fertility management, than organic crop protection. Further analysis of yield, disease and nutrient data is planned using multivariate techniques, to explore hypotheses about the relationships among these variables. This information will be used to formulate improved management strategies and crop resistance breeding targets for organic barley production systems.

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Disclaimer

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