Multiple diseases, host resistance and the role of variety mixtures for disease control in organically grown spring barley

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Background and objectives

One of the most important disease management components in organic farming is the use of disease resistant varieties. It is challenged by the presence of more than one disease that commonly occurs in farmers' fields at the same time. Because, while many modern spring barley cultivars possess good resistance to individual diseases, cultivars resistant to multiple diseases are still scarce since breeding for multiple disease resistance is a difficult and lengthy task. Using mixtures of cultivars possessing high levels of resistance to individual diseases may therefore be a viable option to control multiple disease complexes in organic farming. To ensure an efficient use of variety mixtures in managing multiple disease problems, the presence, nature and effects of interactions among the genotypes used in mixtures (Fig. 1) as well as among the occurring pathogens (Fig. 2) must be understood. The? refers to aspects of multiple disease development and -control as well as aspects of crop performance such as crop health status and final yield. Research was initiated in Denmark in 2002 to study the effects of resistance properties of individual spring barley varieties and their mixtures on the disease development of two important foliar pathogens, leaf scald (*Rhynchosporium secalis)* and net blotch (*Pyrenophora teres* [conidial stage *Drechslera teres*]). The objectives of this work are to:

1) Evaluate the effects of variety mixtures, as compared to pure stands, in controlling the disease development of competing leaf pathogens.
2) Examine the interactions among competing leaf pathogens and their effects on the development of diseases complexes and crop performance.
3) Describe and model the dynamics of epidemics caused by competing leaf pathogens as affected by host resistance diversity.

Materials & methods

In a field trial with spring barley conducted on the organically cultivated area of the DIAS research farm in Flakkebjerg, Denmark in 2002, three variety treatments (1 - pure stand of variety Goldie, 2 - pure stand of variety Punto, 3 - Goldie and Punto in a 50%-50% mixture) were combined with four disease treaments (1 - non-inoculated control, 2 - net blotch inoculated, 3 - net blotch inoculated + scald inoculated at early tillering stage, 4 - net blotch inoculated + scald inoculated after tillering) in a fully randomised two-factorial design with three replications. The plot size was 2.5 x 2.5 m and the plots were surrounded by a 2.5 m border planted (to) with ?? oats. Net blotch inoculation was done by spreading infested winter barley straw after crop emergence. Wheat straw was spread on control plots. For scald inoculations, conidia suspensions were sprayed onto the plots. From tillering until flag leaf emergence, the plots were sprinkler-irrigated 3 x per day: 10 minutes in the evening, at night and in the morning, respectively, to provide optimum moisture conditions for sporulation, spore dispersal and infection. Crop growth stage, % diseased leaf area and % healthy leaf area were visually assessed in each plot 5 x during the growing season. The % net blotch- and scald severity as well as healthy leaf area averaged across observation dates were subjected to analyses of variance (ANOVA) and T-tests.

Results

Net blotch developed most rapidly in the plots inoculated with net blotch alone, followed by the plots inoculated with net blotch plus scald (Fig. 3, upper part). Substantial net blotch levels developed also in the non-inoculated control plots. Scald levels remained comparatively low in the whole trial. However, the late scald inoculation resulted in highest scald levels (Fig. 3, middle). The healthy leaf area was clearly higher in the non-inoculated control plots throughout the whole season, compared to the treatments inoculated with net blotch or net blotch plus scald (Fig. 3, lower part). The disease treatment factor thus had a dominant, highly significant effect on all independent variables (mean net blotch severity, mean scald severity and mean healthy leaf area). Interactions between the treatment factors were non-significant (Tab. 1). Parameterising the disease treatment effects indicated that the inoculation with net blotch alone clearly resulted in highest mean net blotch severity and lowest mean healthy leaf area, followed by the treatments that included scald inoculation (Tab. 2, lower part). The late scald inoculation resulted in the highest mean scald severity levels. Although the variety treatment factor had a significant effect only on the mean net blotch severity (Tab. 1), the parameterisation of the variety treatments (Tab. 2, upper part) indicated a lower mean net blotch severity and a higher mean healthy leaf area of the variety mixture, as compared to the average of the pure stand treatments.

Figure 1. Growing varieties in mixture: hypothetical effects on crop performance. If varieties grown in mixture do not interact, the relationship between mixing ratio and crop performance will be linear. Antagonism among varieties leads to less-than-additive-, synergism to greater-than-additive effects.

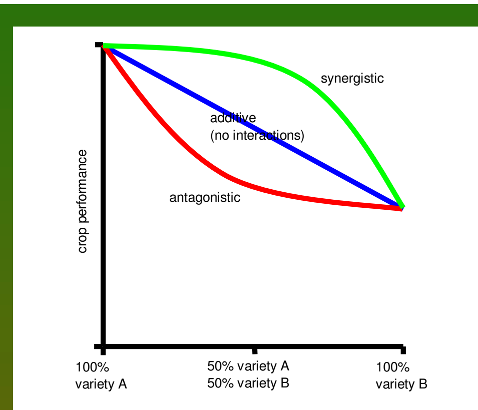


Figure 2. Examples of types of competition between two pathogens, A and B. The green circle symbolises the metabolic pool of the crop that is available to the pathogens. The blue and red ovals stand for the portions of the metabolic pool that will be allocated to the respective pathogen.

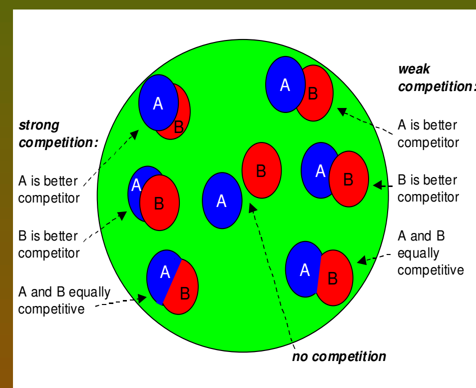
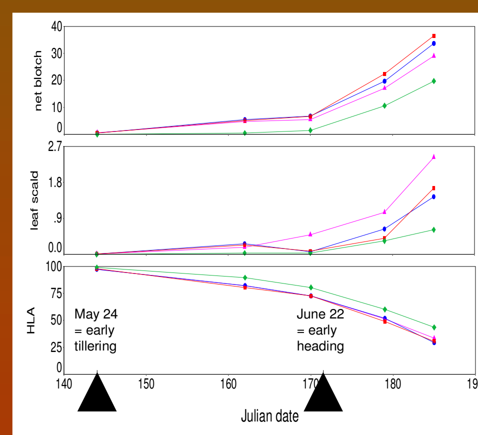


Figure 3. Development of % net blotch severity, % leaf scald severity and % healthy leaf area by disease treatment across variety treatments.

Disease treatment:
- control (non-inoculated)
- net blotch inoculated
- net blotch + early scald inoculated
- net blotch + late scald inoculated



Conclusions and outlook

The first years' results showed that occurrence of both diseases in combination led to less-than-additive effects on disease severity of the predominant disease (net blotch) and crop performance (healthy leaf area) as compared to single-disease scenarios. This indicates antagonism between the disease organisms and has direct implications for disease-yield loss relationships and yield loss appraisal. There were hints for higher-than-additive effects of variety mixtures in reducing disease severity and improving overal crop performance. This indicates potential benefits of using variety mixtures, as compared to pure stands, in controlling disease complexes. The study will be expanded to include additional varieties and their mixtures as well as more aspects regarding the time of establishment and amount of initial inoculum of the two pathogens. The data will be used to develop a simulation model for the development of the two competing diseases as affected by resistance properties of individual varieties and variety mixtures and to derive decision aids for optimising the use of variety mixtures in the management of multiple diseases.

Table 1. ANOVA results: significance levels (p) of F values of variety- and disease treatments and replication with respect to net blotch- and scald severity and healthy leaf area averaged across observation dates.

source of variation	dependent variable:		
	net blotch severity	leaf scald severity	healthy leaf area
variety treatment (V)	0.025	0.613	0.057
disease treatment (D)	0.000	0.015	0.000
replication	0.393	0.002	0.018
V * D	0.145	0.154	0.411

Table 2. ANOVA results: treatment parameters and their significance levels (T-test) as compared to the reference treatment; ns = non-significant; *, ** = significant at p = 0.05 and 0.01, respectively.

treatment	dependent variable:		
	net blotch severity	leaf scald severity	healthy leaf area
variety:			
Goldie	-1.579 ns	-0.538 ns	-0.889 ns
Punto	3.066 ns	0.202 ns	-2.000 ns
mixture (= reference)	0.000	0.000	0.000
disease:			
control (non-inoculated)	-2.587 ns	-0.695 *	3.600 ns
net blotch	5.644 **	-0.618 ns	-5.044 *
net blotch + early scald	2.100 ns	-0.514 ns	-2.733 ns
n. b. + late scald (= ref.)	0.000	0.000	0.000