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The effects of uneven, patchy cultivar mixtures on disease control and yield in winter barley

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ABSTRACT

Three winter barley cultivars were mixed in equal proportions but in different ways to give different patterns of spatial heterogeneity. The mixtures were sown in large field plots over three successive years and disease severity and yield were compared between the mixtures and the mean of the components grown as monocultures. Most mixtures significantly reduced disease in all years. The mixture composition, which appeared to generate a discrete pattern of small patches of the component cultivars, gave a yield advantage in 2 years, while the mixture which was pre-mixed most homogeneously gave no significant yield advantage in these trials. The cost of homogeneous mixing is therefore unlikely to be recovered in increased yields, compared with a simpler, imprecise mixing of the components in the seed hopper prior to sowing.

1. Introduction

Mixing cultivars of cereals in field crops has been used to reduce disease and enhance yield, for many years (Finckh et al., 2000; Mundt, 2002), but monocultures still dominate global cereal crop cultivation. In a few countries, e.g. Poland, mixtures are grown extensively (Gacek et al., 1996), as their greater yield stability is particularly valued. Reasons for the limited uptake of mixtures in UK include lack of market demand and the perceived requirement for extra operational costs of mixing the components. End-users perceive problems with heterogeneity for grain processing, but the contributions of environment and genotype × environment interaction (G × E) to variability are reduced within mixtures compared to monocultures, when sourced over a range of sites (Swanston et al., 2006). Consequently, heterogeneity need not be problematic where mixture components are carefully chosen. Those mixtures which are grown in the UK, notably winter barley, tend to comprise just two components, but experimental work shows both the magnitude and reliability of benefits from mixtures are positively correlated with component number (Newton et al., 1997), so greater improvement is achieved by mixing three or more components. There is also a perception that mixtures are more appropriate for low-input and organic systems. Whilst disease reduction is particularly desirable in such systems where other options are restricted, there is clear evidence that mixtures also perform well in intensive systems (Finckh et al., 2000).

It is commonly assumed by growers and the seed trade that, within mixtures, the component cultivars should be blended in a homogeneous manner. Machinery designed to mix grass seed is often used to mix cereal seed before sowing. However seed of different sizes, in the same bags, may settle out differentially, so, in practice, the beginning and end of a mixed batch will differ in composition (R Don, SASA, personal communication). Additionally, evidence from epidemiological studies indicates that deploying 'patches' of different, individual varieties, each covering an area of several square metres, may offer more effective reduction of pathogen spread than the homogeneous mixtures (Newton and Begg, submitted for publication). Therefore, in addition to imposing extra costs, pre-mixing of seed may not be the best strategy for controlling disease in a crop.

Heterogeneity, at a field or landscape scale, is encouraged to minimise epidemics in cereal crops, with aids such as the diversification schemes to reduce the spread of diseases such as yellow rust (*Puccinia striiformis*), published together with UK Recommended Lists for Cereal Varieties (www.hgca.com). The effects of 'patchiness', i.e. discrete areas sown to individual cultivars, are recognised at such landscape scales (Plantegenest et al., 2007) and may possibly be enhanced by additional application, at a finer scale, in the cultivation of a crop. The scale of deployment has, however, been a key to the large effects

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observed, such as those with rice mixtures over 200,000 ha in China (Zhu et al., 2000) or barley mixtures throughout the former German Democratic Republic (Wolfe, 1992). However, it has not been demonstrated whether patchiness on a 'within-field' scale is beneficial or practical for disease control and yield increase, compared to more homogeneous mixing, although the empirical evidence, in the ecological literature, is that decreasing host patch size reduces disease overall (Colling and Matthies, 2004; Ericson et al., 1999). In current practice farmers can go to some expense to avoid such patchiness in cultivar mixtures.

On the farm, it is not practical to sow regular patch sizes of mixture components with standard commercial farm drills. Sowing drill-width strips may be possible but unlikely to achieve much benefit as the patch size would be too large, in one-dimension at least. The only practical way to achieve a patchy crop mixture, and one being used on some farms, in practice, is to crudely or coarsely mix the component cultivars as they are put in the drill seed hopper. Even here there are strategies which would achieve very different outcomes in the field. We have tried to mimic some drill loading strategies in a commercial farm drill to achieve uneven sowing of cereal crops with different spatial characteristics. In particular, we aimed to determine whether sowing with different degrees of patchiness is practical, and whether it is more beneficial than homogeneous mixing of seed for reducing disease and increasing yield.

2. Materials and methods

2.1. Field trial 2005

A winter barley trial was sown over three consecutive years in the same field but using different treatment randomisations. In 2005 the cultivars Siberia, Pastoral and Sumo were used, but in 2006 and 2007 Sumo was not available and was replaced with Pearl (Table 1). Siberia is a six-row cultivar and the others are two-row types. The site was an exposed, south-facing slope with grade 2, slightly stony soil. In 2005 the plots measured 175 m long by 6 m wide, i.e. two passes of a Vaderstad Rapid 300C 3 m drill, always sowing up the slope, to a density of ~360 seed/m^2. Plots were separated from each other by a 1.0-m gap and alternate pairs of plots were separated by a 3-m wide plot of a guard cultivar to allow tractor access. Standard herbicide and fertilisers treatments were applied but no fungicides. There were seven trial entries which were randomised in each of four replicates. Siberia, Pastoral and Sumo were sown as monocultures. The fourth entry was 'pre-mix' where all three cultivars were homogeneously mixed prior to loading into the drill hopper. Entry five, '*in situ*', comprised each of the cultivars being put in the hopper in sequence then crudely mixed by hand. Entry six, 'simultaneous', comprised all three cultivars being poured into the centre of the hopper simultaneously. Entry seven, 'sequential', was simply each of the three cultivars being put in the hopper in sequence and left without further mixing. All mixtures were in equal proportion of component cultivars by weight. The expectation was that 'pre-mix' would have a homogeneous distribution, '*in situ*' would have coarse or discrete small patches, 'simultaneous' would likely be quite well mixed but a tendency to be 'stripy' as seed would tend to have a degree of vertical structure in the hopper, and 'sequential' would be monocultures with stripy interfaces between them as one cultivar runs out and the next replaces it at different rates across the hopper. This latter spatial pattern in particular could result in replicate differences being larger than with conventional trials. Each mixture was created in the drill hopper then sown in replicate 1, then 2, then 3, then 4.

Diseases were scored on a 1–9 scale where 1 was no disease and 9 was 100% diseased (Newton and Hackett, 1994) in 20 places on each side of each plot. Ordinal scores were converted to percentage infection equivalents before analysis of variance (ANOVA) was carried out using Genstat 10th Edition (Payne et al., 2007).

2.2. Field trial 2006 and 2007

In 2006 and 2007 the plots were 164 m long but otherwise were sown in the same format as the 2005 plots. A fungicide treatment was introduced by defining four 36-m sections of the plots with 4 m discards between the sections and at the ends. There were alternately defined as fungicide treated (f1) or control (f0). The fungicide treatments applied in 2006 were in recommended rates of Unix + Opus + Amistar + Bravo at T1 followed by Opera + Bravo + Opus at T2. In 2007 the T1 treatment was Proline + Amistar Opti and the T2 was Opus + Comet + Bravo. Diseases were scored in five places on each side of each f0 sub-plot and analysed as above.

2.3. Yield measurement

In 2005, each 3-m wide drill strip of each plot was harvested using a Massey Ferguson 28 combine and the grain was weighed in a trailer on a public weighbridge. In 2006 and 2007 each sub-plot (two f0 and two f1 from each plot) was harvested separately and weighed in a 700-l box pallet on a Tru-test Eziweigh 2 weighing platform. As for disease data, yield data was subject to ANOVA using Genstat.

3. Results

3.1. Yield data

In 2005 the harvest was successful but a problem was encountered with the public weighbridge. It was noted that weights varied depending upon the position where the trailer was parked on the bridge, and whilst variation in this position was minimised as much as possible, that such a problem existed means that the accuracy of these data should be treated with caution, although the replicate c.v. was only 3.4%. The in-field weighing platform used for the 2006 and 2007 harvests solved the reproducibility problem and proved reliable and accurate. In 2005 only one of the mixtures gave a statistically significant

Table 1
Variety characteristics (HGCA recommended lists).

Cultivar	Yield (% of controls)			Traits						Trial year			
	+fung	−fung	Lodging	Height	Maturity	Winter hardiness	Mildew	Rhyncho	Net blotch	Rec. list year	2005	2006	2007
Siberia	104	83	8	94	−4	4	5	8	5	(2007)	×	×	×
Pastoral	96	76	7	93	−2	(7)	3	7	5	(2005)	×	×	×
Sumo	97	77	8	94	0	5	7	5	8	(2005)	×	–	–
Pearl	99	79	7	105	0	5	6	7	5	(2007)	–	×	×