Assessing the contribution of component cultivars to malting quality, yield and disease in complex cultivar mixtures

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Background

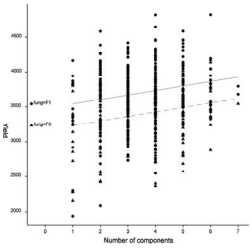
- Mixtures of varieties grown together reduce disease and increase yield
- Mixtures increase yield stability
- High grain quality markets will not accept mixtures because of perceived problems with heterogeneity
- In practice malting quality is not compromised and can be enhanced

Field experiment

- Seven winter barley cultivars: Maris Otter, five with Maris Otter in their pedigrees (Halcyon (Warboys x Maris Otter), Pipkin (Sergeant x Maris Otter), Puffin ((Maris Otter x Athos) x Igri), Rifle (Puffin x NRPB87/5381), Gleam (Puffin x Torrent)) and Melanie (W5907 x Br301a)
- Three replicate split plot design using with and without disease control as the main plot
- Agronomic assessments: Yield, powdery mildew, rhynchosporium
- Quality assessments: extent of cell wall modification (CWM), homogeneity of CWM (HOM), hot water extract (HWE), fermentability (FERM), Predicted Spirit Yield (PSY), soluble nitrogen content (SN%)

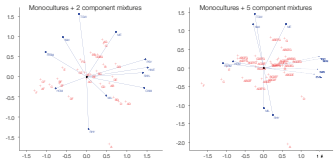
Yield results

Figure 1. Plot of yield against mixture component number, showing the fitted regression line with (solid line) and without fungicide.



Effect of mixtures on all assessments

Figure 2. Biplots demonstrating the relationship between yield, disease and quality parameters in monocultures and mixtures of winter barleys with Maris Otter in their pedigrees.



A = M. Otter, B = Halcyon, C = Puffin, D = Pipkin, E = Rifle, F = Gleam, G = Melanie.

Table 1 Mean values for assessment parameters for component cultivars.

	M. Otter A	Halcyon B	Puffin C	Pipkin D	Rifle E	Gleam F	Melanie G	Best Mix	Best Value	SED
Yield (g/plot)	2168	3234	3385	3221	2856	3917	3846	ABCFG	4054	230.3
Thousand Grain Weight (TGW) (g)	41.1	45.0	45.9	39.0	49.3	43.0	50.2	AG	53.0	1.26
Cell Wall Mod. (CWM) (%)	52.5	42.6	18.2	74.5	27.1	18.1	54.9	AD	80.3	7.64
Homogeneity (HOM) (%)	31.5	28.0	45.2	40.2	42.5	43.9	40.4	AF	54.4	6.09
Hot Water Extract (HWE) (L°/kg)	286.0	287.6	268.5	301.5	263.4	246.5	296.7	AD	304.8	6.28
Fermentability (FERM) (%)	85.6	86.3	87.6	85.3	87.4	87.2	86.8	BEFG	87.3	0.65
Soluble Nitrogen (SN%) (%)	0.52	0.53	0.43	0.54	0.39	0.37	0.53	AD	0.57	0.032
Predicted Spirit Yield (PSY) (L/tonne)	385.4	390.6	370.2	404.4	361.9	338.5	405.4	ABCDEG	407.8	8.65
Mildew† (MIL)	18.57	1.03	8.84	30.00	3.02	2.42	1.81	BEG	1.64	3.402
Rhynchosporium† (RHY)	0.90	1.64	2.42	0.85	1.64	1.21	0.00	AG	0.00	1.830

Mean values from ANOVA except for FERM, which was taken from REML including batch effect. †SED = standard error of difference of the means. TAKE, RHY values are angular-transformed percentages

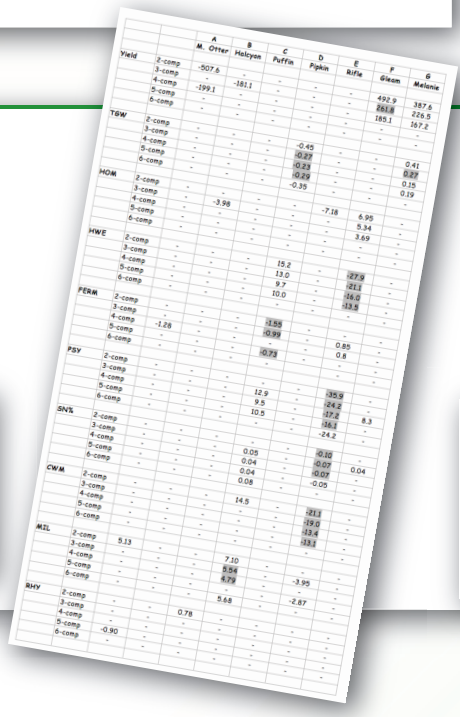


Table 2 Mean effects of component cultivars for malting quality characteristics and yield in mixtures of winter barley with different component numbers.

Shaded data indicates F probability <0.001. Non-shaded data indicates F probability between 0.05 and 0.001.

	A M. Otter	B Halcyon	C Puffin	D Pipkin	E Rifle	F Gleam	G Melanie
Yield							
2-comp	-507.6					492.9	387.6
3-comp						161.8	226.5
4-comp						185.1	167.2
5-comp	-199.1	-181.1					
6-comp							
TGW							
2-comp				-0.45			0.41
3-comp				-0.27			0.29
4-comp				-0.23			
5-comp				-0.29			
6-comp				-0.35			0.15
HOM							0.19
2-comp							
3-comp							
4-comp	-3.98			-7.18		6.95	
5-comp						5.34	
6-comp						3.69	
HWE							
2-comp							
3-comp			15.2			-27.9	
4-comp			13.0			-21.1	
5-comp			9.7			-16.0	
6-comp			10.0			-13.5	
FERM							
2-comp							
3-comp	-1.28		-1.55				
4-comp			-0.99				
5-comp						0.85	
6-comp			-0.73			0.8	
PSY							
2-comp							
3-comp							
4-comp			12.9			-35.9	
5-comp			9.5			-24.2	
6-comp			10.5			-17.2	8.3
SN%						-14.1	
2-comp						-24.2	
3-comp							
4-comp			0.05			-0.10	
5-comp			0.04			-0.07	
6-comp			0.08			-0.07	0.04
CWM						-0.05	
2-comp							
3-comp							
4-comp			14.5			-21.1	
5-comp						-19.0	
6-comp						-13.4	
MIL	5.13					-13.1	
2-comp							
3-comp			7.10				
4-comp			5.54				
5-comp			6.79			-3.95	
6-comp							
RHY			5.68			-2.87	
2-comp							
3-comp			0.78				
4-comp							
5-comp	-0.90						
6-comp							

Table 3 Cultivar mixtures showing significant interactions ($p < 0.001$) for yield, disease and quality components. The number shows the size and sign of the interaction effect (in addition to the mean of the monoculture effects).

	Yld	TGW	ME	HOM	HWE	SN%	PSY	CWM	Mil	Rhy
AB										-2.93
AC										-2.93
AD	193.80				10.19				-4.36	-2.71
AE	179.90									-2.66
AF	175.70			11.03	-13.11	-0.07	-15.87	-16.89		-2.55
AG	144.50	0.29	34.80							-2.61
BC								11.79		
BD		-0.22								
BE		-0.15	-38.96				12.05			
BF								-8.78		
BG										1.72
CD		-0.20								
CE		-0.16						12.69		
CF		-0.17			-9.36					
CG										
DE	180.60	-0.28		-10.55	13.78		17.35			
DF		-0.20						-18.21	-5.91	
DG								-11.38		
EF	144.70	-0.16	-25.73							
EG										
FG		-0.17								1.93

Conclusions

- Three cultivars gave strong interactions with multiple traits when deployed in complex mixtures.
- Yield response of the mixtures was up to 15% more than the component monoculture mean.
- The contribution of specific cultivar traits to mixtures showed a dilution effect over 2-, 3- and 4-component mixtures.
- The most complex mixtures also perform best for yield and disease control.
- PSY showed a positive response only in the most complex mixture.
- At all levels of complexity, there was no disadvantage of mixtures compared to the monoculture mean for HOM.
- Pipkin and Gleam, however, showed effects that were consistent across all levels of complexity.
- Biplots clearly showed that desirable yield and quality were not well correlated, but yield was strongly associated with TGW.
- Measurement of the percentage variance accounted for provides a tool to make quantitative decisions about mixtures composition for different purposes.
- Other than some combinations with Maris Otter, notably with Gleam, few other particular pairings need be avoided.

Acknowledgements
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