Within-crop genetic diversity increases temporal yield stability in organic winter wheat

NICK FRADGLEY, SALLY HOWLETT and MARTIN WOLFE

The Organic Research Centre, Wakelyns, Fressingfield, Suffolk, IP21 5SD
E-mail: nick.f@organicresearchcentre.com

INTRODUCTION

Organic farming represents a farming system aiming to develop alternatives to unsustainable inputs such as mineral fertilisers and pesticides. Such systems are inherently more variable and therefore require varieties that are resilient to multiple uncontrolled biotic and abiotic stresses. Evolutionary plant breeding, using genetically diverse Composite Cross Populations (CCPs) has been proposed as an approach to dealing with these stresses.

WHAT IS A CCP?

A Composite Cross Population (CCP) is created by inter-crossing selected parent varieties in all combinations (**fig 1**). The resulting F1 hybrid plants produce segregating F2 populations which are bulked together and grown in the field. Segregation and natural selection over a number of generations then leads to populations comprising very large numbers of homozygous but genetically distinct lines (**fig 2**). This diverse bulk of lines is then grown and harvested so that the best performing genotypes produce more seed and contribute more to the following generation so that the composition of the CCP is constantly evolving according to the environment in which it is grown.

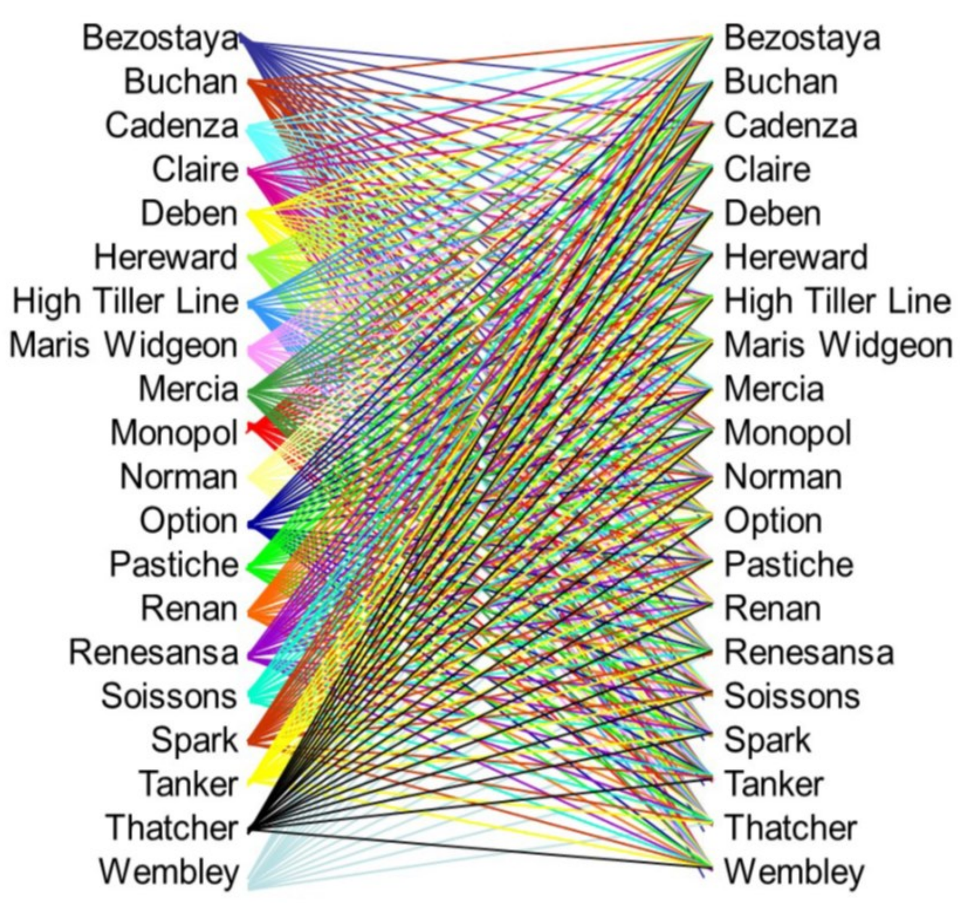

Figure 1. Crossing scheme for the 20 parent ORC composite cross populations.

Figure 2. The resulting crop of diverse ORC YQCCP grown at the organic site.

MATERIALS AND METHODS

Field trials investigated the yield stability of an 8 parent (NIAB MAGIC Elite CCP) and a 20 parent (ORC YQ CCP) winter wheat CCP compared to the physical mixtures of their parental varieties as well as high yielding (c.v. Alchemy) and high quality (c.v. Solstice) elite pure-line control varieties at an organic and a non-organic site in the east of England over four harvest years (2010—2013).

Measures of yield stability for these trial entries over time include Coefficient of Variation (CV%), static stability (b) (Finlay & Wilkinson, 1963), dynamic stability (δ^2) (Eberhart & Russell, 1966) and Wricke's Ecovalence (W^2) (Wricke, 1962).

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RESULTS

Average yields of all trial entries over the four years were lower at the organic site than at the conventional site. The CCPs, with greater genetic diversity than varieties and respective mixtures, demonstrated better dynamic and static yield stability at both sites (**fig. 3 & table 1**). Differences in average yields among trial entries were only marginal at the organic site. However, the control varieties were consistently higher yielding than the mixtures and populations at the conventional site.

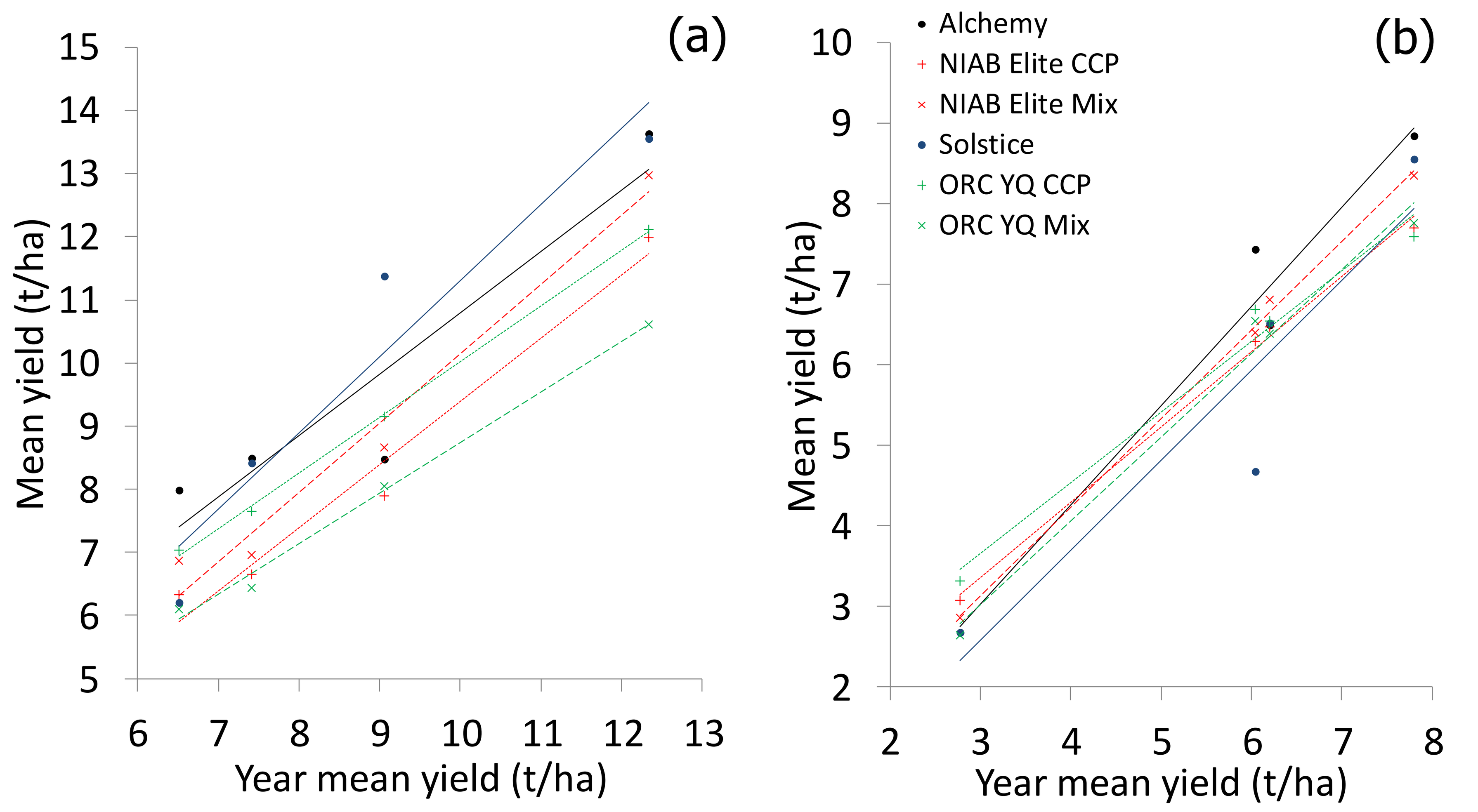

Figure 3. Joint regression analysis showing static yield stability (gradient of line) and dynamic stability (distance of points from line) of trial entries at the conventional (a) and organic (b) sites. Solid lines represent control varieties, dashed lines represent mixtures and dotted lines represent CCPs.

Table 1. Values of mean grain yield and yield stability for the varieties, mixtures and populations. Most favourable scores are highlighted in bold whilst least favourable are in shown red.

		Organic site					Conventional site				
		Mean yield (t/ha)	CV%	Static stability (b)	Dynamic stability (δ2)	Wricke's Ecovalence (W^2)	Mean yield (t/ha)	CV%	Static stability (b)	Dynamic stability (δ2)	Wricke's Ecovalence (W^2)
Varieties	Solstice	5.6	38.9	1.12	2.31	2.26	**9.9**	28.3	1.21	2.61	3.26
	Alchemy	**6.4**	36.0	1.23	0.70	1.65	9.7	23.9	0.97	2.68	3.04
Mixtures	NIAB Elite Mix	6.1	33.0	1.10	0.03	0.21	8.9	28.0	1.10	0.69	0.99
	ORC YQ CCP	5.8	32.8	1.04	0.22	0.37	7.8	**22.8**	**0.80**	0.08	0.84
Populations	NIAB Elite CCP	5.9	29.1	0.93	**0.05**	**0.15**	8.2	27.4	1.00	0.59	0.72
	ORC YQ CCP	6.0	**26.9**	**0.88**	0.24	0.53	9.0	21.8	0.88	**0.02**	**0.31**

CONCLUSIONS

- Diverse CCPs are able to maintain yield in the most adverse (low yielding) environments but their yield potential is limited in high-input (higher yielding) environments.
- CCPs are a useful tool for organic farming or low input farming systems, where biotic and abiotic stresses, such as limited nutrients, weed competition and crop diseases, are expected.
- Yield stability is a more useful measure of variety performance in organic systems than average yield per se.
- As such, yield stability will be increasingly important in dealing with unpredictable stresses over time, including those caused by global climate change and increasingly limited resources.

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