Results

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Introduction

This field lab aims to look at wheat varieties that are best suited for organic use, grown on organic land under organic farming systems. A replicated trial will use current and potential UK and European wheat varieties that are selected for their organic potential. It will assess old, current and varieties not currently available in the UK for yield and milling quality in UK farming conditions. The UK is a more maritime region than many parts of Europe with a different disease profile, and different requirements from the buyers. Pearce Seeds are also undertaking a trial in Dorset using the same varieties, and so we will be able to compare the varieties between different sites. This trial is also contributing to initiate a variety testing platform for organic wheat, with potential extensions to other species.

Materials and methods

Experimental site and crop management

The trial has been carried out at on a typical Cotswolds brash field (shallow chalky stony loam) with pH 8.1, 9.4 ppm available P, 66 ppm available K, 41 ppm available Mg, 8.3% organic matter. The trial was drilled at a 480 seeds/m^2 rate with a plot driller on the 27th October, after the soil was ploughed and harrowed. Harvested was performed with a plot combine on the 15th August. The season has been characterised by a prolonged and cold winter and an unusually dry and warm summer (Fig. 1).

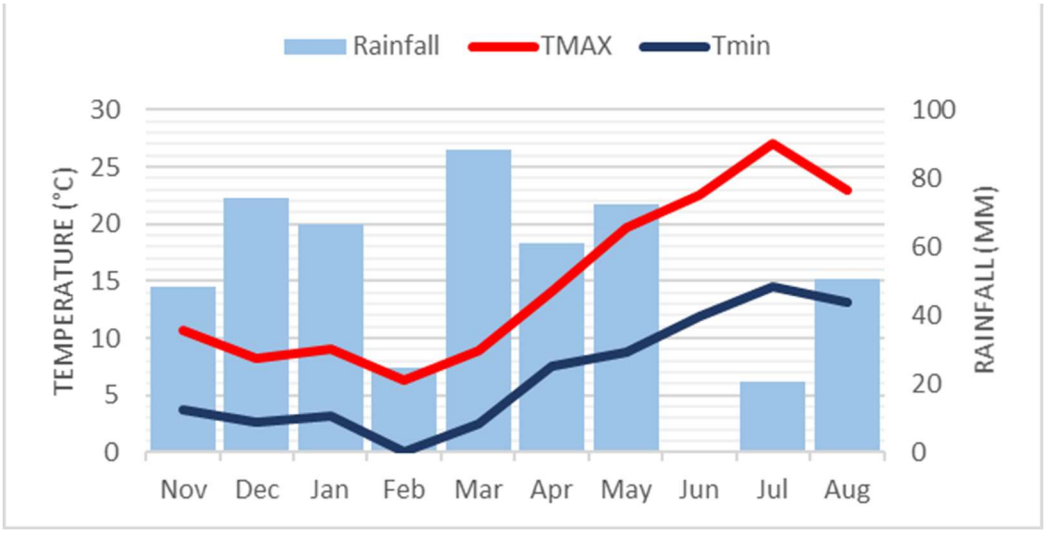

Fig. 1. Monthly climatic data as recorded at the Oxford Weather Station (metoffice.co.uk)

Varieties

The trial included 17 varieties:

- Anapolis
- AWC13
- Costello
- Crispin
- Crusoe
- Dunstan
- Gleam
- Gourmet
- Graham
- Maris Widgeon
- Mortimer
- Olympus
- Revelation
- Siskin
- Skyfall
- Sundance
- Zyatt

Varieties Mortimer and AWC 13 were also included at a reduced sowing rate of 430 instead of 480 seeds/m^2.

Samplings and assessments

The variables and traits assessed were as follows:

- Crop establishment – visual assessment to detect any remarkable crop failure

A simple visual assessment for each plot to determine crop establishment and make varietal comparisons if evident.

- Growth cycle length - crop phenological stage in correspondence of flowering

The growth stage of each variety using the BBCH scale at a site visit at or around mid-flowering to determine earlier or later varieties.

- Crop canopy height - on a plot basis, in correspondence of flowering (BBCH GS 65)

Measured using a ruler to give a representative canopy height across the plot.

- Diseases severity – on a plot basis.

Identification of main diseases and estimated average percentage cover of flag leaf and 2nd leaf in correspondence of BBCH GS 65 on at least three plants per plot. A severity percentage value has been estimated averaging the infected area of the 2nd leaf with twice the infected area on the flag leaf (to highlight the importance of infection of flag leaf, as it carries the most of photosynthesis).

- Ears density – count of fertile tillers on two randomly selected linear row meters in each plot

Counts of ears along a row meter to provide an estimate of ear numbers per meter squared.

- Grain yield – plot combine harvest of each plot at maturity, with grain weight adjusted at 14% moisture

Each plot harvested to provide a kg/plot grain weight and a moisture content to allow conversion to t/ha and standardisation to 15% moisture.

- Grain quality

Protein content, thousand grains weight and grain specific weight (hectolitre weight) on a bulk grain sample from each variety.

Data analysis

The trial is designed as a randomised complete block, with 19 "treatments" and four replicates. This will ensure a high statistical power in detecting differences between varieties. Data were analysed by a linear model to highlight effect of variety over any response variable. Validity of the model was checked graphically observing the diagnostic plot of residuals (quantile-quantile plot). Pairwise comparisons between varieties was carried out through the Tukey's HSD test. All analyses were done by R version 3.4.3 (2017-11-30) on a x86_64-w64-mingw32/x64 (64-bit) platform.

Results and Discussion

Crop observation during the flowering stage (Table 1) highlighted differences among varieties in terms of height and disease susceptibility. Maris Widgeon had an outstanding canopy height (82.5 cm on average) compared to the bulk of the other varieties, all ranging between 57 and 67 cm.

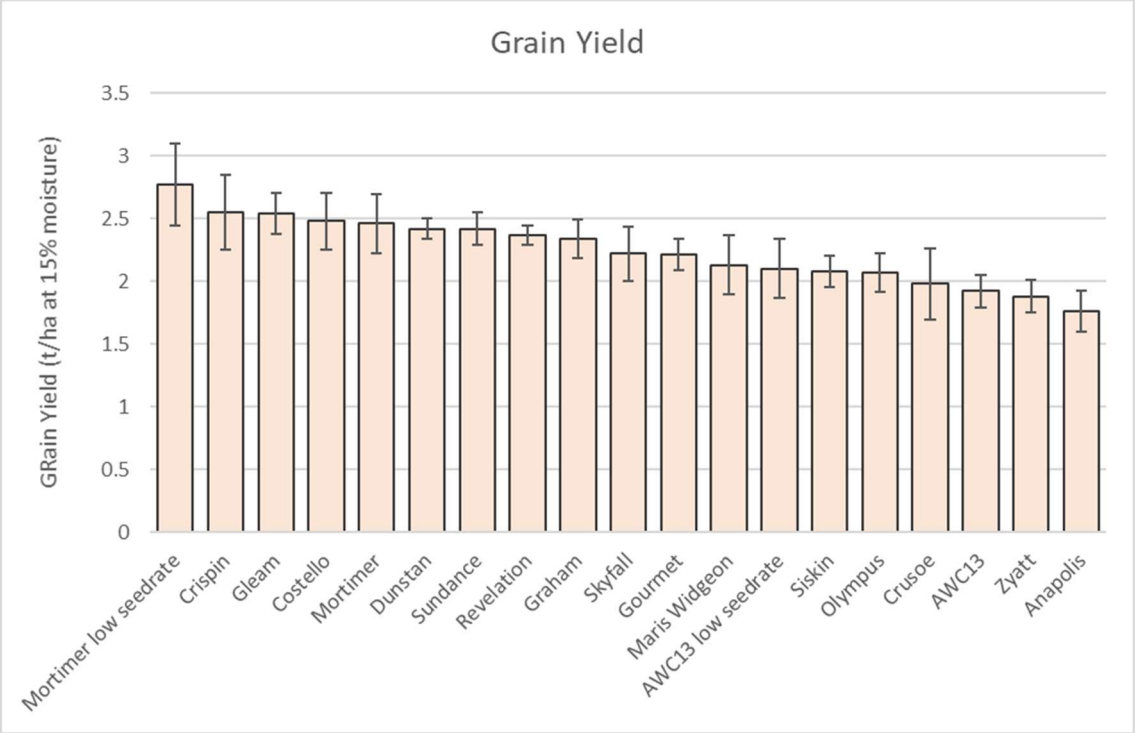

Fig. 2. Grain Yield of the tested varieties. Bars indicate the mean; error bars indicate the standard error of the means.

We observed presence of the three major foliar diseases:

- Septoria was observed in all varieties except Crusoe and Skyfall, with relatively low severity not exceeding 11%, and with no significant differences among the affected varieties;
- Yellow rust was only present in variety Skyfall with a high severity of 43%;
- Brown rust affected with a medium severity var. Crusoe (10%).

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Table 1. **Results of the field assessment carried out at flowering (BBCH GS 65) including canopy height, Septoria, Yellow rust and Brown rust severity and ears density**
values followed by the same letter are not significantly different according to Tukey's HSD test

Variety	Height	Septoria	Yellow rust	Brown rust	Ears density
	(cm)	*(% severity)*	*(% severity)*	*(% severity)*	*(ears/m²)*
Anapolis	63.0 bc	7% ab	0%	0%	175.0 ab
AWC13	66.0 bc	3% ab	0%	3%	226.7 ab
AWC13 430	65.0 bc	5% ab	0%	0%	201.7 ab
Costello	62.0 bcd	5% ab	0%	0%	213.3 ab
Crispin	61.5 bcd	8% ab	0%	0%	186.7 ab
Crusoe	62.5 bcd	0% b	0%	10%	186.7 ab
Dunstan	66.0 bc	4% ab	0%	2%	**256.7 a**
Gleam	61.0 cd	5% ab	0%	0%	230.0 ab
Gourmet	67.0 b	4% ab	0%	0%	206.7 ab
Graham	61.0 cd	11% a	0%	1%	**265.0 a**
Maris Widgeon	**82.5 a**	8% ab	0%	0%	183.3 ab
Mortimer	64.0 bc	8% ab	0%	0%	195.0 ab
Mortimer 430	65.0 bc	8% ab	0%	0%	218.3 ab
Olympus	64.0 bc	10% a	0%	0%	**141.7 b**
Revelation	64.0 bc	5% ab	0%	0%	220.0 ab
Siskin	64.0 bc	4% ab	0%	0%	180.0 ab
Skyfall	57.0 d	0% b	43%	0%	218.3 ab
Sundance	62.0 bcd	4% ab	0%	0%	213.3 ab
Zyatt	64.0 bc	6% ab	0%	0%	203.3 ab
field average	*64.3*	*5.3%*	*2.2%*	*0.8%*	*206.4*

Ears counts highlighted that the trial was, in general, underperforming: average ear density was 206.4 ears/m², which is about a half of what is supposed to be an optimal range. Such underperformance was confirmed at harvest, with an average grain yield of 2.25 t/ha. Yields spanned across a range between a minimum of 1.78 t/ha of var. Anapolis, and a maximum of 2.80 t/ha of var. Mortimer at 430 seed/m². However, statistical analysis did highlight significant differences between varieties (Anova p = 0.001, Tukey's minimum significant difference = 0.82 t/ha) with Mortimer (lower seed rate) yielding significantly better than Zyatt, Anapolis and AWC13. Protein and specific weights were also low compared to optimal values, with 6.14% and 65.6 kg/hl on average, respectively (Table 2, Fig.2, Fig. 3).

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Protein content and yield are linked by a highly significant negative correlation (r = - 0.87; p = 0.000 ***), with the lowest protein content detected in the top yielding variety and vice-versa. Observing the distribution of varieties across a trendline representing this trade-off, as represented in Fig. 4, we can suggest that varieties Olympus, Siskin and Skyfall fell below the trendline, therefore with lower protein than expected according to their yield, whereas varieties Maris Widgeon, Graham and Gourmet tended to be above the trendline, suggesting that they could have been more efficient in harvesting proteins.

Table 2. Harvest and post-harvest data: Mean yield ± standard error, grain protein content, specific weight and thousands kernel weight.
values followed by the same letter are not significantly different according to Tukey's HSD test

Variety	Yield	Protein	Specific weight	Thousands Grain Weight
	t/ha adj. 15% moisture	*% adj. 15% moisture*	*kg/100l*	*g*
Anapolis	1.78 ± 0.17 b	7.1	66.5	35.0
AWC13	1.94 ± 0.13 b	6.5	67.4	33.1
AWC13 low seedrate	2.13 ± 0.24 ab	6.5	66.9	35.4
Costello	2.50 ± 0.23 ab	5.7	69.7	35.2
Crispin	2.57 ± 0.30 ab	5.7	65.1	33.0
Crusoe	2.00 ± 0.29 ab	6.6	64.2	34.3
Dunstan	2.44 ± 0.08 ab	5.7	64.6	37.1
Gleam	2.57 ± 0.16 ab	5.9	66.9	36.3
Gourmet	2.24 ± 0.13 ab	6.4	67.2	35.9
Graham	2.36 ± 0.16 ab	6.3	64.0	35.1
Maris Widgeon	2.16 ± 0.24 ab	6.6	69.3	38.1
Mortimer	2.48 ± 0.24 ab	5.8	66.3	37.0
Mortimer low seedrate	2.80 ± 0.33 a	5.5	67.8	41.5
Olympus	2.08 ± 0.15 ab	6.1	61.0	34.9
Revelation	2.39 ± 0.08 ab	6.1	64.8	33.8
Siskin	2.10 ± 0.13 ab	6.1	63.9	33.0
Skyfall	2.24 ± 0.22 ab	5.9	66.8	35.8
Sundance	2.43 ± 0.13 ab	5.7	58.7	31.6
Zyatt	1.90 ± 0.13 b	6.5	65.0	34.9

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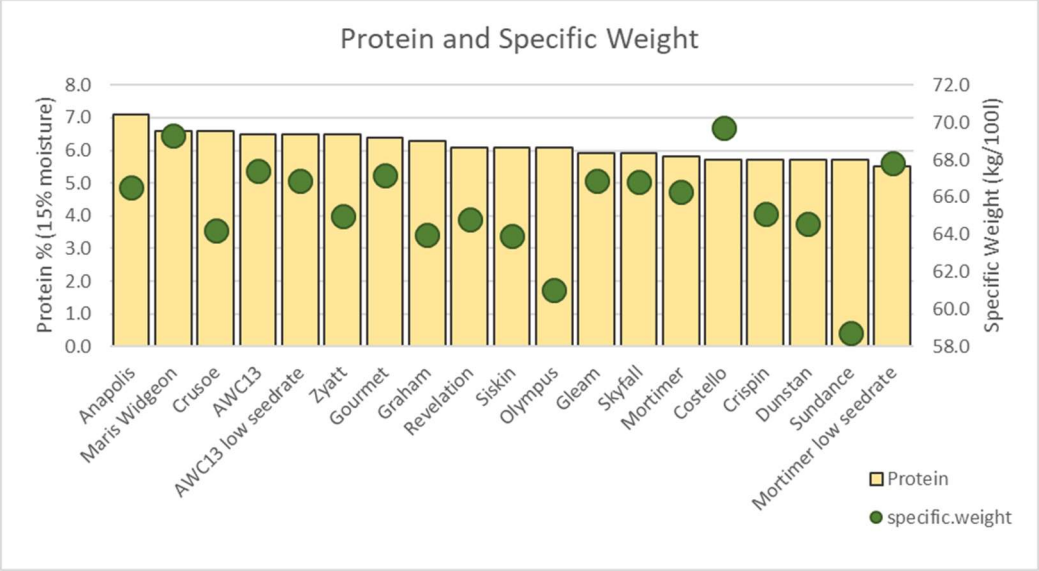

Fig. 3. Grain protein content (bars) and specific weight (points) of bulk grain samples of the tested varieties.

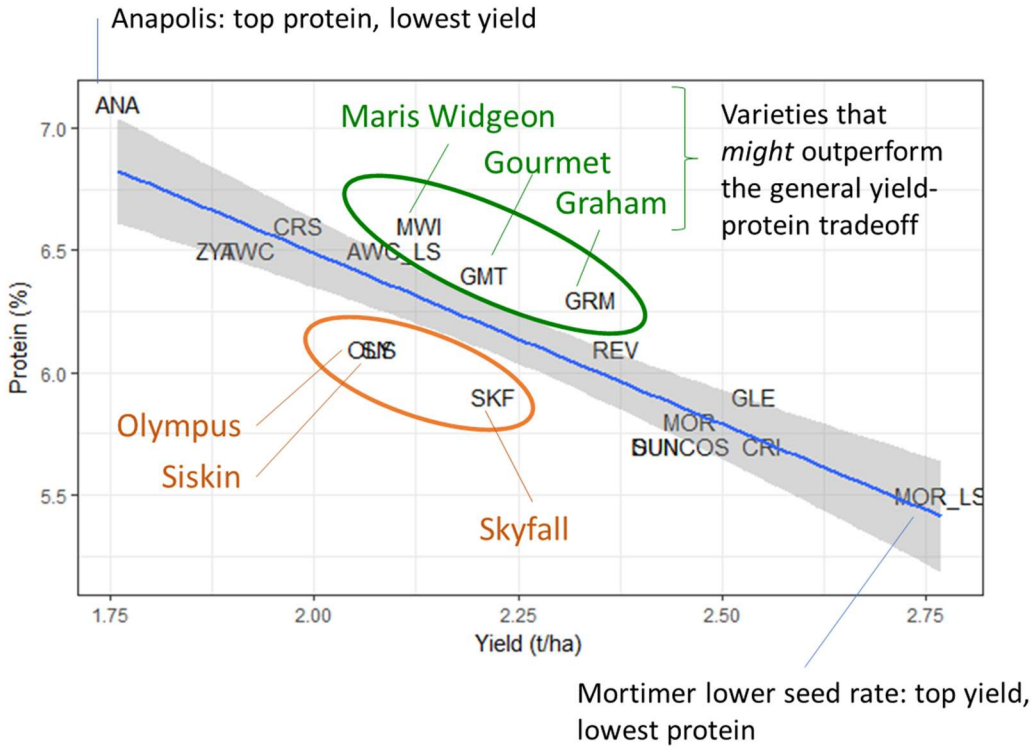

Fig. 4. Relationship between grain yield and protein content, with the line of best fit (blue line) and the 95% confidence interval (grey area). Varieties falling outside the grey area might be considered to deviate from the yield-protein trendline, either positively (above) or negatively (below).

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Conclusion and next steps

Conclusions about varietal performance must be taken cautiously because the trial has been run for one year only. However, this trial has a value outside its results as it embeds all the pros and cons aspects of a plot trial. In fact, **the general underperformance of wheat in this trial is in part linked to the plot structure itself** and to its artefacts (especially machinery not representative of farm machinery, delays in drilling due to availability of the plot drill): the average yield of the trial was evidently lower than the yield of the surrounding commercial field of variety Revelation, which was about 3.8 t/ha, i.e. 58% more than the same variety in the plots. However, **a plot trial is the only way to compare a relatively large number of varieties** in the same environment and to draw a general profile of their performance. For example, specific constraints in terms of diseases have been identified, and correlation between yields and quality are possible without other "confounding" variables.

Merging data from this trial with the data from the parallel trial run by Pearce Seeds in Dorset will strengthen both trials, confirming and/or correcting the trends identified. Testing a restricted number of varieties at a field scale with a network of farmers, whilst maintaining a reference plot trial is by far the best compromise to draw conclusions about varietal performance in organic systems.

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