Disease, varieties and seed treatments in Organic Cereals

The Defra funded project "Cereal Varieties for Organic Production: Developing a Participatory Approach to Seed Production and Varietal Selection" has just completed its second of four years and led by EFRC in collaboration with NIAB, Middlesex University, University of Kingston, HDRA and around 20 organic farmers in the south and east of England. Here **Jane Thomas and Rosemary Bayles** of NIAB describe some of the work they have been doing during the 2003/04 season as part of this project.

Testing organic cereal seed for seed-borne disease

Tests have been completed on a total of 174 samples, predominantly wheat. Samples were obtained from organic seed producers, farm saved organic seed from growers, and seed harvested from organic variety trials. Levels of *Microdochium nivale* (seedling blight) were high on some samples of wheat. Levels of bunt (*Tilletia tritici*) were generally low, and below the threshold for treatment in conventional seed, though a small number of lots had higher levels, and in one case a seed bulk was considered unsuitable for further organic production. *Cochliobolus sativus* (foot rot) was recorded at high levels in a specific seed lot of barley, and *Pyrenophora avenae* (leaf blight) was seen in some organic oat samples.

Comparisons were made between results of samples of conventional seed sent to NIAB for commercial tests, and the organic seed. Though test numbers were very different (eg about 600 samples of conventional wheat seed), there did not appear to be any consistent trend for organic cereal seed to be healthier or less healthy than conventional seed (eg see Figure 1a and 1b). The predominant seed related problem was ergot in wheat, with very high numbers (up to 80) of sclerotia per kg of seed in some samples, but similar levels have been noted recently in conventional seed lots.

Fig 1a: Percentage of samples infected with various seed-borne diseases, 2003, organic and conventional seed (W= wheat, O = oats)

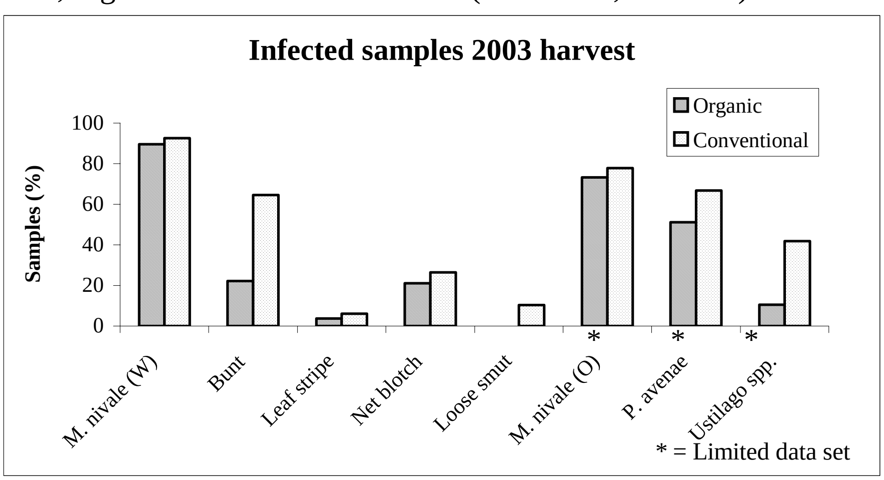
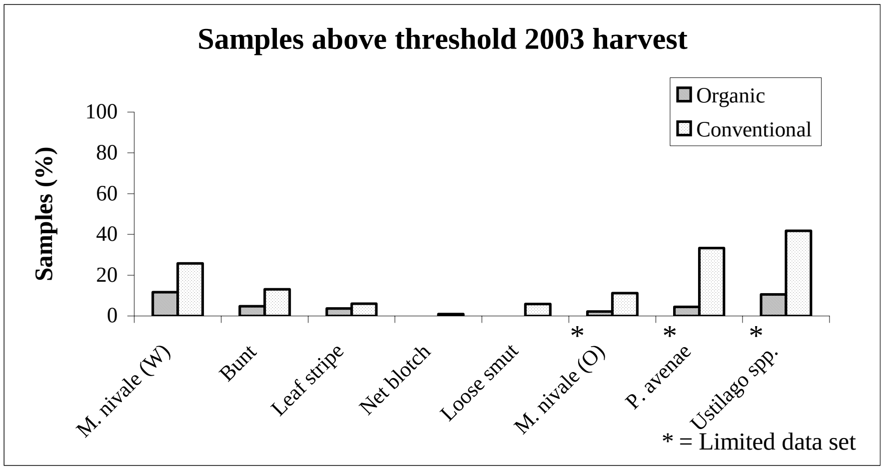


Fig 1b: Percentage of samples above advised seed treatment threshold disease levels, 2003, organic and conventional seed (W= wheat, O = oats)



Organic seed treatment evaluation

A number of seed treatments and processes which are either approved for organic use, or would be highly likely to achieve approval, were applied to diseased seed of wheat (*M. nivale* and *T. tritici*) and barley (*Pyrenophora graminea*, or *Ustilago nuda*). Products were selected to represent a) “chemical” b) physical, or c) biological applications. Treated seed was sown in replicated 12 m plots in autumn 2003, together with untreated seed and conventional product controls. Appropriate records of the occurrence of seed-borne disease expression, plant growth and yield were taken (wheat still to be harvested). The trial was carried out on non-organic land due to the problems associated with some products, and the introduction of diseases such as bunt and loose smut onto organic holdings. Preliminary results indicate that the hot air treatment used as a physical process reduced bunt in wheat to some extent. This treatment clearly reduced establishment as well, though in the barley trial yield was not significantly reduced.

Controlling seed-borne disease with variety resistance

Trials in 2004 consisted of a second season of investigation for all diseases, and sowing out of seed infected in the previous year. The preliminary analyses of results are summarized below:

Bunt (*T. tritici*): For winter wheat varieties, there was good consistency between 2003 & 2004 data, with Hereward and Solstice again showing good resistance and other varieties being fairly susceptible. As in 2003, all spring wheat varieties tested were susceptible to bunt. Winter triticale varieties were totally uninfected for the second successive year.

Ergot: For winter wheat, there were some inconsistencies between 2003 and 2004 infection levels: in 2004, all varieties tested were susceptible, although Nijinsky (= Socrates) showed some resistance in both years. Spring wheat varieties were also all susceptible in 2004; Chablis appears to be slightly less susceptible, having no infection in 2003 and lower levels than other varieties in 2004. All four winter triticale varieties tested were very susceptible in both years. All winter and spring oat varieties tested showed no infection in either 2003 or 2004.

Barley leaf stripe: It is difficult to draw any conclusions for this disease, as the method of spraying spore suspension onto ears produced little infection in harvested seed or resulting plants “grown-on” in 2004. There was a suggestion that the spring barley variety Dandy may be slightly more susceptible than others but this will require confirmation in 2005. It may be necessary to devise a more invasive ear infection method to test varieties for resistance to leaf stripe.

Loose smut: The winter wheat varieties Exsept and Xi19 exhibited high levels of infection in both embryo and 2004 “growing-on” tests; Claire, Deben and Nijinsky appeared to be more resistant. For spring wheats, there was inconsistency between results of embryo tests and growing-on tests in the field and it is difficult to draw conclusions. All winter barley varieties tested were susceptible to loose smut; spring barley data is not yet complete, although Optic may be slightly more susceptible than other varieties.

M. nivale ear blight: The winter wheat variety Exsept had low levels of ear blight in both years; Claire and Deben had lower infection than most other varieties in 2004 only. There was poor correlation between field assessment data and subsequent levels recorded on the seed in agar plate tests. All spring wheat varieties tested were moderately susceptible in both years and there was better correlation between ear and seed infection. Winter oat varieties ranked the same in both years, with Millennium showing the most infection and Kingfisher the least, although infection levels in the field and on the resulting seed were low. The spring oat Firth appeared to be more susceptible than other varieties in both years and had correspondingly higher seed infection.

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2004 CEREALS REVEAL AN INTRIGUING SURPRISE.

The great variability in the performance of cereals on organic farms that we have highlighted from past research trials has been confirmed in a new and more widely based trial. Participation from 20 producers gives the results a robust character and has enabled us to spot something we had not previously noted. EFRC researchers Prof Martin Wolfe AND Kay Hinchsliffe set out the results.

Introduction

EFRC is currently working on a Defra-funded project designed to use participatory research and development methodology, and is conducted on sites across the country with the participation of 20 farmers, seed producers and more than 10 researchers (EFRC, NIAB, Middlesex University, University of Kingston & HDRA). The idea is to integrate the contributions of different stakeholders into developing a robust system for identifying, testing, multiplying and marketing cereal varieties, lines, mixtures, and populations best suited to organic production in different parts of the country .

Three high quality winter wheat varieties, Hereward, Solstice and Xi 19 and their mixture, were selected for the trial based on their performance in previous years' replicated variety trials. Participating farmers drilled each variety in strips (total area of 1/10 ha) surrounded by their own winter wheat crop. This article summarizes data from the first year of field trials (2003-4); since this is the first year they should be treated with caution. The trial is being repeated and has already been planted by essentially the same group of participating farmers.

Yield Survey

Yield data in Figure 1 shows the overall variability in yields from 15 sites with a 2.5 fold spread, from the least to highest; this variability is a result of variety, system and site level interactions. System differences can include resource availability, weed species and prevalence, sowing date, rate and method. Site differences include for example, soil type, climate and landscape.

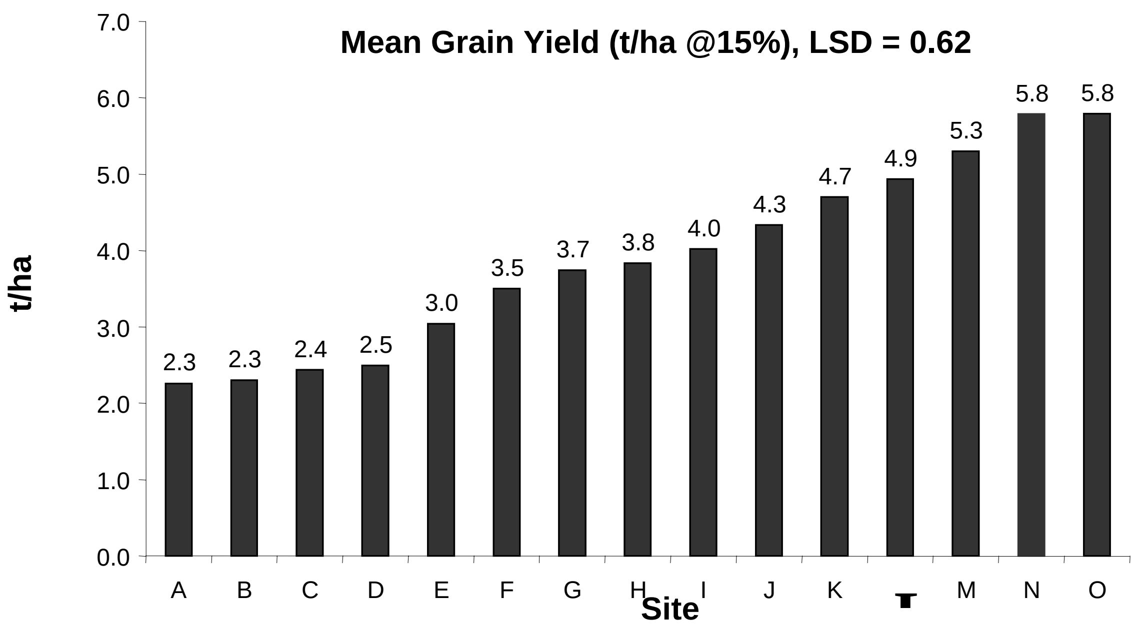

***Figure 1.* Mean grain yield from successful harvests from 15 trial sites.**

Variety variation:

a. Yield

Table 1. shows the variability and unpredictability of ranking of the varieties within and among sites. Most important, it also shows that the range of yields among varieties is considerably less than the range of yields among sites.

Site	Yield range	Rank 1	Rank 2	Rank 3	Rank 4
A	0.77625	S	H	M	X
B	0.713	M	S	H	X
C	0.99245	H	S	X	M
D	0.9292	X	S	M	H
E*	*	*	*	*	*
F	1.16955	X	H	M	S
G	2.51965	H	S	X	M
H	0.5543	M	S	X	H
I	1.0925	M	H	S	X
J	1.03615	X	S	H	M
K	2.5829	M	H	X	S
L	1.18105	X	M	S	H
M	2.6404	X	S	H	M
N	2.139	H	M	S	X
O	1.55825	H	S	X	M
All Sites	**3.490825**				

Table 1. Yield range of the three varieties and their mixture at each site together with their rank order. The yield range for all sites is also given. H= Hereward, M= Mixture, S= Solstice and X= Xi 19 (* data missing for one variety).

Despite such variability in yield there is an indication that Hereward may be higher yielding than Xi 19 (average yield for Hereward was 4.2 t/ha and Xi 19 was 3.8 t/ha), although this was not statistically significant. This contrasts with data from conventional trials in which Xi 19 consistently outyields Hereward. However, more comprehensive analysis of the yield data shows that average yield for all varieties and the mixture at all sites was 4 t/ha and that there was 95 per cent probability that all varieties would achieve this average. In other words, on statistical grounds, there was no clear advantage for choosing any one of the varieties at any one site.

b. Quality

Analysis of quality data revealed, similarly to yield, considerable variability in the data, in this case for Hagberg Falling Number (HFN) and protein content. For example the range of mean HFNs across sites was 169-328s, and the range for protein was 7.6 to 11.1 per cent dry matter. Among the varieties, the ranges of mean values were 212 to 245s and 8.5 to 9.1 per cent dry matter. These generally low HFNs could have been due to the wet summer and delayed harvest. However, the data did show that Hereward had a significantly higher HFN than the other varieties ($p<0.005$), and that Xi 19 was the most variable, although this was not statistically significant. Differences in protein content among varieties were small, particularly in relation to the differences among sites.

c. Variety mixture

Perhaps unexpectedly, the most variable yields were from the mixture. From past experience mixtures have often out yielded most or all of their components and given a stable, high yield over many sites, particularly under conventional conditions. Under such conditions, disease is often a limiting factor so that the ability of mixtures to restrict diseases has a clear advantage. However, under organic conditions, with no synthetic inputs, all biotic and abiotic aspects of the environment are variable and it appears that the three variety components within the mixture interacted differently at each trial site.

One major factor was probably that Hereward, as the potentially highest yielding variety, was also the shortest. From Figure 5, the mixture had a greater cumulative straw length than the three component varieties indicating that Hereward may have been suffering from competition from both Solstice and Xi 19.

Site variation: short/tall straw

A closer look at the yield data revealed that the sites fell into two distinct categories, those with "short" plants (<40cm) and those with "tall" plants (>50cm) (Figure 2). It is also apparent that "short" plants were on average higher yielding relative to "tall" plants (Figure 3.). At the "tall" sites there appeared to be a positive correlation between height and yield. This was not evident at the "short" sites.

Interestingly, all "tall" sites were in the East of England, whereas all "short" sites were in the West, suggesting that climate differences between East and West might be important in determining height.

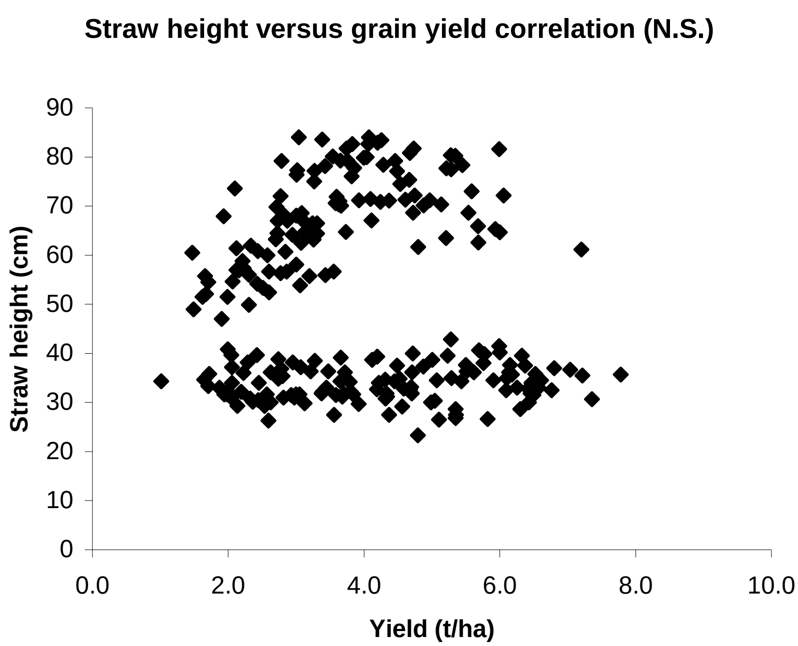

***Figure 2*. Straw height against grain yield for all varieties at all sites**

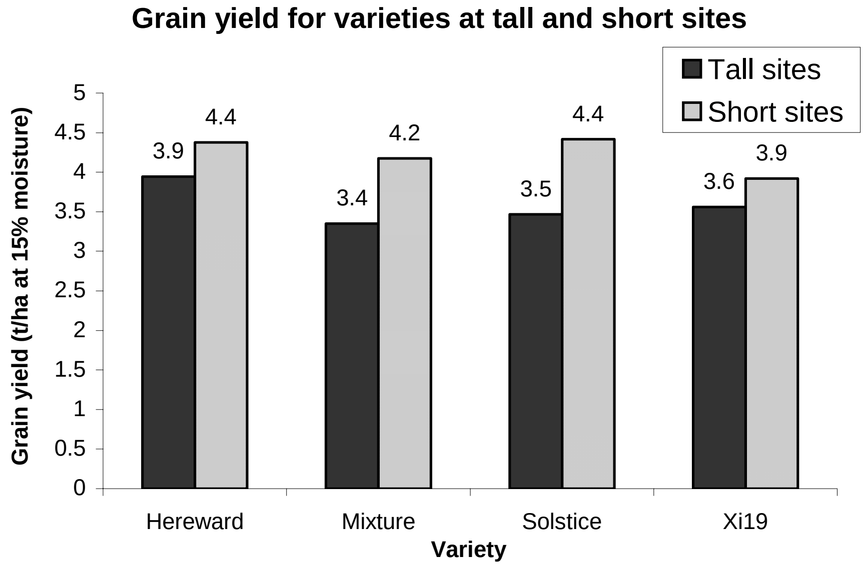

***Figure 3.* Grain yield for varieties at "tall" and "short" sites**

The average yield of all varieties at "tall" sites varied between 2.5 and 3.74 t/ha (mean of 3.58 t/ha), whereas at the "short" sites it lay between 2.3 and 5.3t/ha (mean of 4.18 t/ha).

Higher mean yields at "short" sites could be attributed to a greater number of heads per unit area than at "tall" sites (Figure 4). However, the number of heads/m^2 at "short" sites is one third to one half more than that at "tall" sites, whilst the difference in yield among the sites was not so pronounced. This implies either fewer grain per ear or a lower thousand-grain weight at the "short" sites, which we will report on at a later date.

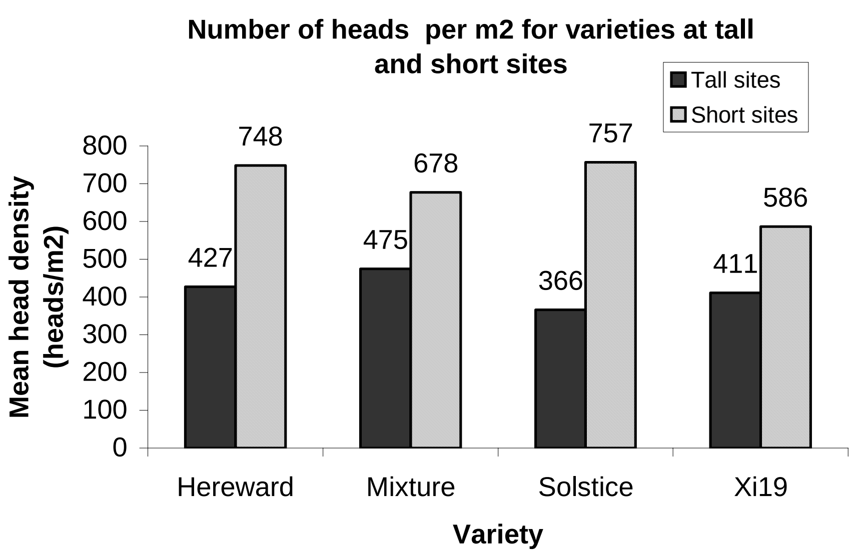

***Figure 4.* Average number of heads per unit area for varieties at "tall" and "short" sites**

Comparing the “tall” and “short” sites for total straw production showed that the “tall” sites produced more straw than the “short” sites. In other words, the greater number of heads per unit area at the “short” sites was insufficient to compensate for the height of the straw at the “tall” sites (Figure 5).

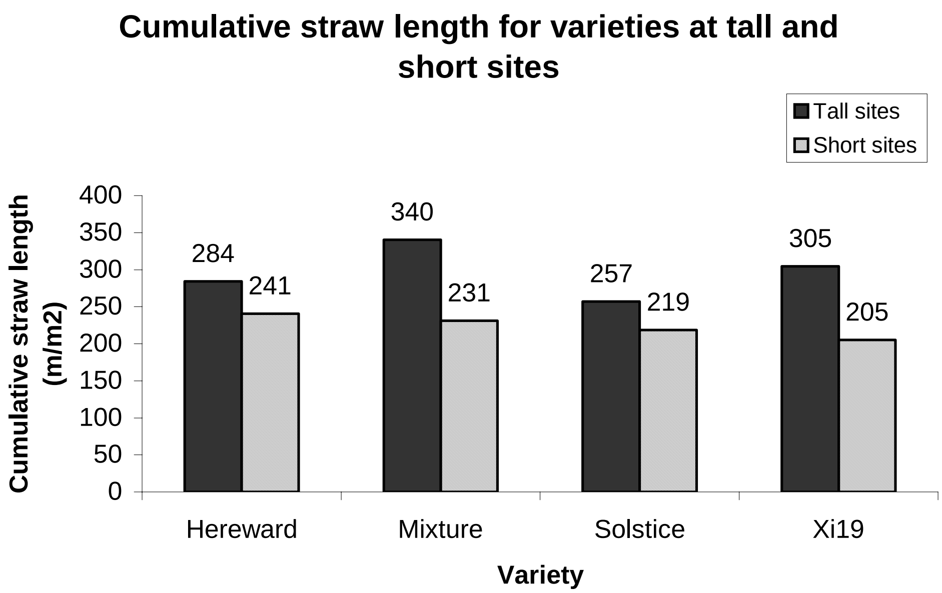

Figure 5. **Cumulative straw length for varieties at “tall” and “short” sites.**

Site variation: Interpretation

Organic systems are characterised by the non-use of synthetic inputs. A major consequence is that the crops being grown are exposed to a wide range of environmental variables both biotic and abiotic. As a consequence we expect yield and quality to vary among sites. What we did not expect in this set of trials was that the variation would show a strict East/West divide. It is difficult to explain the reasons for this division except to say that it probably derives from interactions among system, local climate and soil type affecting crop growth.

What is important to point out is that the yield and quality variation among the varieties used in this experiment was considerably less than the site and system variation.

Data provided by farmers allowed us to explore whether straw height was related to soil type. Light soils produced greater yield (5.1 t/ha) on average than heavy soils (3.3 t/ha). From heavy to light soils there is a decreasing proportion of “tall” sites and an increasing proportion of “short” sites (Figure 6.). It remains to be seen whether this can be confirmed in 2005. Whether or not this is so, we still are unable to explain the relationship between soil type and growth pattern.

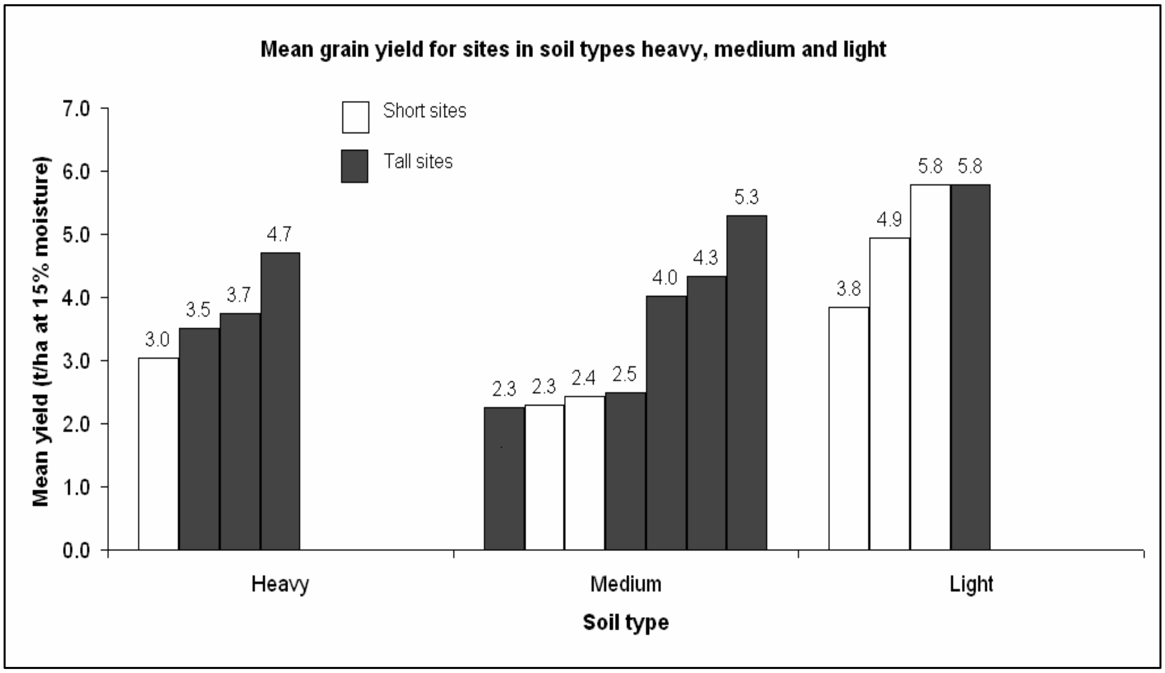

Figure 6. **Mean grain yield for sites on heavy, medium and light soil types.**

The trend for higher yield on light soils compared to heavy was consistent for all varieties. However, the ranking of varieties differed on soil types. Hereward performed best on medium and heavy soils, whilst the mixture performed better on light soils.

System variation

In order to assess the effects of variation among systems, we looked at previous crop, sowing date and seed rate. Previous cropping was similar at most sites comprising of a two-year ley with usually red, or white clover. There was no obvious correlation with yield or crop height. Seed rate was variable again with no obvious correlation with yield or height. There was a slight positive correlation between seed rate and lateness of sowing, as expected, but this explained less than 10 per cent of the variation.

The only factor that appeared to have an effect was sowing date. At both “tall” and “short” sites crops sown later tended to produce a greater yield than those sown earlier (although this was not significant). It may be that lighter soils (which tended to have higher yields) provide an easier opportunity for late sowing.

CONCLUSIONS

- This participatory trial has provided us with a unique opportunity to analyse the performance of leading wheat varieties on a wide range of organic farms. Such an approach benefits the whole community of farmers.
- Yield and quality were highly variable among both sites and varieties, with many changes in rank at different sites. Statistical analysis suggests that it would have been reasonable to grow any one of the three varieties or the mixture at any site.
- Curiously, the fifteen sites divided into two major clusters either with “short” straw or ““tall”” straw. These clusters were related to geographical position

("short" in the West, "tall" in the East). This major effect common to crops of all three varieties used may have been due therefore to interactions among crops, systems, soil types and climatic factors.

- Plots at the "short" sites had more stems per unit area than those at the "tall", but the numbers of stems did not compensate totally for straw height in terms of total straw length per unit area.
- The major finding of the trials was that environmental variation (climate, soil and system) was probably far more important as a determinant of wheat yield and plant form than was either farming system or plant variety. We are checking for confirmation of this conclusion by repeating the same trial in 2005.
- Research and development is urgently needed to develop major changes in both systems and genetic variation; these play a central role in the EFRC programme.
- In the meantime, a practical way forward would be for farmers and researchers to collaborate in following the performance of specific varieties and mixtures on a wide range of farms.
- In relation to genetic variation, we are optimistic about potential gains to be made from our project on the development of composite cross populations in wheat; it is important that this should proceed as a form of participatory plant breeding.

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