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SID 5 Research Project Final Report

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Project identification

1. Defra Project code: OF0330
2. Project title: Cereal varieties for organic production: Developing a participatory approach to seed production and varietal selection
3. Contractor organisation(s): Elm Farm Organic Research Centre
   Hamstead Marshall
   Nr Newbury
   Berkshire
   RG20 0HR
4. Total Defra project costs (agreed fixed price): £ 295,609
5. Project: start date .... 01 August 2002

   end date .... 31 July 2006

6. It is Defra's intention to publish this form.
   Please confirm your agreement to do so...**YES** ☒ **NO** ☐

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   Defra recognises that in a small minority of cases there may be information, such as intellectual property or commercially confidential data, used in or generated by the research project, which should not be disclosed. In these cases, such information should be detailed in a separate annex (not to be published) so that the SID 5 can be placed in the public domain. Where it is impossible to complete the Final Report without including references to any sensitive or confidential data, the information should be included and section (b) completed. NB: only in exceptional circumstances will Defra expect contractors to give a "No" answer.

   In all cases, reasons for withholding information must be fully in line with exemptions under the Environmental Information Regulations or the Freedom of Information Act 2000.

   (b) If you have answered NO, please explain why the Final report should not be released into public domain

Executive Summary

7. The executive summary must not exceed 2 sides in total of A4 and should be understandable to the intelligent non-scientist. It should cover the main objectives, methods and findings of the research, together with any other significant events and options for new work.

Overall Aim
To develop 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.

Objectives
1. Develop a participatory research and development methodology for UK organic farmers using variety trialling and the management of seed-borne disease as examples.
2. Collect information on the range of cereal varieties currently grown by organic farmers to help identify the major priorities and constraints among the varieties available.
3. Establish a pilot programme of cereal variety trials with organic farmers on organic farms using the methodology developed by Objective 1.
4. To obtain information on which seed-borne diseases, including ergot, may cause problems in the organic seed production chain of wheat, barley, oats and triticale, and to examine any relationship between organic husbandry conditions (seed rate, sowing date, rotation etc.) and incidence/severity of disease.
5. Determine whether cultivars with good potential for organic production are resistant to one or more of the seed-borne disease problems.
6. Working with farmers (Objective 1), review and identify a range of organically acceptable seed treatments and processes, considering both chemical and physical methods, and test these under organic conditions to determine efficacy.
7. Formulate a code of best practice for the production of certified organic seed, and for the processing of seed on organic farms.
8. To evaluate the participatory research and development approach throughout the entire research process and produce guidelines and materials for best practice. Data will be collected throughout the duration of the project.

Objective 1. A literature review was undertaken and an agenda for future research set out. Questions to be addressed included: Have we identified the research that farmers and other stakeholders want? What roles do farmers and other stakeholders play? How do we carry out the testing, adaptation and development of options? How can the effective forms of participatory research (if there are any) be 'mainstreamed' into other agricultural research?

Existing systems of farmer involvement in research were also examined through interviews with farmers, agri-businesses and scientists. It was found that almost all farmers were carrying out some kind of research on their farm. This may be using scientific methods or using a more holistic approach with multiple criteria. Farmers may set hypotheses explicitly before starting the experiment or they may use gut feelings and be experimenting without acknowledging it. They also often changed treatments during the experiment. It was concluded that the best results are more likely to come when topics are addressed by combining farmers' own research with research on farms controlled and managed by scientists.

From discussions with various farmer groups and the previous experience of Elm Farm Organic Research Centre researchers, it was decided that: the project should focus on winter wheat; and the basic experimental protocol must be simple, be able to be undertaken by the farmer with their own machinery and within the farmers' time constraints. A protocol was established and reviewed each year at annual post harvest review meetings.

Objective 2. Planting data was collected from the members of the Organic Arable Marketing Group in the first year of the project. Hereward and Claire were the most popular winter wheat varieties grown, and this was confirmed by a survey of the farmers involved in this project. A major concern of farmers was achieving milling quality specifications (especially protein concentration).

Objective 3. Plots of three bread making winter wheat varieties (Hereward, Solstice and Xi19) and a mixture (1:1:1) of the varieties were grown at up to 19 UK farms in two seasons (2003/04 and 2004/05). Measurements were taken of growth habit, yield and grain quality. Grain yields in both seasons showed significant site by variety interactions, although the variation among sites was greater than among varieties in both instances. Wheat grown at Western sites was significantly shorter and higher-yielding than that grown at Eastern sites in 2003/04 but significantly taller in 2004/05. As with grain yield, greater variation among sites than varieties was found in the Hagberg Falling Number and protein concentration results in both seasons. The results from the two years of trials illustrate the variability of organic systems and the difficulty in selecting a single wheat variety suitable for organic farms.

Garlic oil was used as a seed treatment for Hereward on two of the sites in the second year of trials. However, the treatment had no effect on establishment of the variety, and yields were variable.

Benchmarking data was collected from 24 farms. Exsept appeared to be the highest yielding variety and yields varied with soil type (silts>clays>sands). More data would be needed to give an accurate picture of organic yields across the country.

Objective 4. A total of 676 samples were tested between 2002 and 2005. Treatment thresholds for wheat seed have recently been extensively investigated and revised, producing a safe level below which untreated seed could be sown. Results showed that most samples had higher health status than the conventional treatment thresholds. However, there were occasional problems, most notably in the case of bunt on wheat, where very high levels of infection were seen, and the seed would have been unsuitable for further multiplication as seed, or for ware production. It was not possible to relate these occurrences consistently with any particular farm practice, with the possible exception of one site where minimum tillage was used, and the crop was always a second wheat. Ergot (*Claviceps purpurea*) was present at high levels (e.g. over 50 pieces per kg of seed) in several samples, but ergot infestation has also been increasing in frequency and severity in conventional production recently. *Microdochium nivale* sometimes reached high levels on wheat seed in seasons favourable to the disease, but similar levels were also seen in conventional samples received for testing at NIAB.

Objective 5. Tests on appropriate varieties were carried out in 2 years. Of the wheat varieties: Hereward and Solstice appeared to show 'resistance' to bunt although the nature of the resistance is not known; Exsept, was consistently more resistant to *Microdochium* in the ear than other varieties; and Claire, Deben and Nijinsky appeared to be more resistant to loose smut than other varieties. There has been little effort to breed for seed borne disease resistance but these results indicate that it should be possible to introduce resistance, especially for diseases like loose smut.

Objective 6. Seed treatment trials were carried out in 2004 and 2005 and comprised examples of biological, micronutrient and physical treatments. None of the treatments used in 2004 significantly improved establishment when wheat seed had a high level (30%) of *Microdochium nivale* seedling blight, and none significantly increased final yield. In 2005, one of the biological treatments tested (from Crompton Ltd) did significantly improve plant establishment, though effects on yield were non-significant. Both biological products (Cerall and the Crompton product) suppressed bunt in 2005, as did Radiate (ammonium and zinc ammonium complex), though the latter had no significant effect in 2004. The hot air treatment also reduced bunt in 2005, though the effect was less marked in 2004.

Seed cleaning was also investigated as a means of improving establishment in *Microdochium* infected wheat. Though establishment counts and early spring counts were improved slightly in the cleaned seed compared to uncleaned, effects were not significant, and final yields were not improved. Incidence of disease in the cleaned versus uncleaned seed (% infection on agar plates) was similar, indicating that the process, although removing light and shrivelled seed, did not selectively remove infected seed.

Objective 7. The code of best practice for seed production concentrated on bunt since this was the most prevalent problem found in this project. Guidelines included: always test untreated 'mother' seed; seed destined for further multiplication should have as close to 0 bunt spores/seed as possible; seed for crop production should have no more than 1 bunt spore/seed; grow farm-saved seed as first wheat; and sow wheat early to minimize any chances of infection.

Objective 8. The participatory process was assessed three times using interviews with farmers and researchers involved in the project. It was evident that farmer participatory research was more complicated, time-consuming and expensive than expected. Key issues identified included:

- Acknowledging and addressing the training needs of farmers and researchers at the outset of a project
- Building a team of people (farmers and researchers) who understand each others' background, and are able to work together towards an agreed set of goals.
- Appreciating the commitment farmers must make on top of their existing workloads to engage in this sort of activity, and doing what is possible to facilitate this.
- Identifying appropriate people to act as boundary spanners and draw all stakeholders together in dialogue.
- Within this framework, identifying research goals that can be realistically met by all concerned.
- A short leaflet and a longer document were produced for farmers/researchers setting out what's involved in participatory research and the pros and cons of participating.

Conclusions. The experimental aspect of this project has highlighted the large variation among organic systems and the problems in recommending a single variety to organic farmers. However, the work has shown that there are few problems in the health of the seed used in organic systems. This is particularly important since none of the potential organic seed treatments tested had a positive effect on yield.

The main aspect of this work has been a learning experience in aspects of farmer participatory research in a UK context. Differing views have meant that natural and social scientists have written different parts of the discussion. Researchers have experienced difficulties in engaging farmers and managing their expectations, the challenges of working in multidisciplinary teams spread over different institutions and the extra time needed to build and maintain relationships. Farmer participatory research does have an important role to play in producing both relevant and rigorous results for farmers and funders. It has to be managed appropriately, and has to be recognised that processes are very different to a typical research project.

8. As a guide this report should be no longer than 20 sides of A4. This report is to provide Defra with details of the outputs of the research project for internal purposes; to meet the terms of the contract; and to allow Defra to publish details of the outputs to meet Environmental Information Regulation or Freedom of Information obligations. This short report to Defra does not preclude contractors from also seeking to publish a full, formal scientific report/paper in an appropriate scientific or other journal/publication. Indeed, Defra actively encourages such publications as part of the contract terms. The report to Defra should include:
   - the scientific objectives as set out in the contract;
   - the extent to which the objectives set out in the contract have been met;
   - details of methods used and the results obtained, including statistical analysis (if appropriate);
   - a discussion of the results and their reliability;
   - the main implications of the findings;
   - possible future work; and
   - any action resulting from the research (e.g. IP, Knowledge Transfer).

OVERALL AIM

To develop 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.

OBJECTIVES

1. Develop a participatory research and development methodology for UK organic farmers using variety trialling and the management of seed-borne disease as examples.
2. Collect information on the range of cereal varieties currently grown by organic farmers to help identify the major priorities and constraints among the varieties available.
3. Establish a pilot programme of cereal variety trials with organic farmers on organic farms using the methodology developed by Objective 1.
4. To obtain information on which seed-borne diseases, including ergot, may cause problems in the organic seed production chain of wheat, barley, oats and triticale, and to examine any relationship between organic husbandry conditions (seed rate, sowing date, rotation etc.) and incidence/severity of disease.
5. Determine whether cultivars with good potential for organic production are resistant to one or more of the seed-borne disease problems.
6. Working with farmers (Objective 1), review and identify a range of organically acceptable seed treatments and processes, considering both chemical and physical methods, and test these under organic conditions to determine efficacy.
7. Formulate a code of best practice for the production of certified organic seed, and for the processing of seed on organic farms.
8. To evaluate the participatory research and development approach throughout the entire research process and produce guidelines and materials for best practice. Data will be collected throughout the duration of the project.

OBJECTIVE 1. DEVELOP A PARTICIPATORY RESEARCH AND DEVELOPMENT METHODOLOGY FOR UK ORGANIC FARMERS USING VARIETY TRIALLING AND THE MANAGEMENT OF SEED-BORNE DISEASE AS EXAMPLES.

This objective was met in full as participatory methods were developed using variety trialling and management of seed-borne diseases as examples. The specific areas of work under this project were as follows.

A literature review was undertaken (Annex 1) that examined the different approaches to participatory research in an international context and examined how these could be utilised in the UK. The review covered such areas as organic farming and agricultural research policy, research and innovation by farmers and agri-business, the interactions of scientists with farmers and farm related businesses and then produced a concluding section; An agenda for further research that sets out the issues to be explored in this project and in participatory research approaches in general. These were:

- Have we identified the research that farmers and other stakeholders want?
  - What are the methods of assessments and analyses of farming systems?
  - How do we identify the ideas and options to be researched?

- What are the roles for farmers and other stakeholders?
    - What level of intensity of participation (Sumberg *et al.*, 2002)?
    - How refined should the technology be?
    - Should farmers be trained in scientific research methods?
    - Should the research work with research minded farmers or are these individuals unrepresentative of the farming community?
    - What are the power relations in a partnership?
    - Who is empowered and who is excluded?
    - Who has the time to participate?

- How do we carry out the testing, adaptation and development of options?
    - How can the different objectives of farmers and researchers be reconciled?
    - Should research be done with groups or individuals? Groups reduce the costs of working with farmers and help share knowledge but can exclude some types of farmers and become dominated by particular individuals (Leeuwis, 2000).
    - How can research cope with multiple goals and the weighting of different criteria?

This study has also explored how the effective forms of participatory research (if there are any) can be 'mainstreamed' into other agricultural research.

An examination of the existing systems of farmer involvement in research and dissemination was undertaken through a series of interviews with relevant actors (farmers, agri-businesses and scientists). The report can be found in Annex 2. This study has identified a number of key issues and implications that were used to shape the participatory approaches developed and tested over the period of the project. Based on the detailed interviews with the farmers, agri-businesses and scientists a number of conclusions and implications were drawn.

Conclusions:

- Almost all farmers appear to be doing some form of trials and experimentation although some are more active and less risk averse. Other agri-businesses are also found to be doing experimentation particularly with regard to manufacturing.
- Advisors, seed dealers and other farmers encourage farmers to carry out their own experiments.
- Most experiments concern production with little evidence of marketing research despite the pleas from grain traders for farmers to be more responsive to market demands.
- Some of the farmers' own research is similar to the replicated scientific method, but farmers often have to adjust their treatments during the trial to avoid losing the crop.
- Farmers can use a wide range of criteria to asses a trial in a holistic manner. Analysis is carried out through comparisons to previous years' findings, other fields or farmers or untreated parts of the same field.
- Farmers may also make tacit assessments using gut feelings and incorporate this into future developments. They may not recognise that they have carried out an experiment or done anything different until asked to reflect on what they have done. Knowing how farmers do these types of experiments and build up tacit knowledge is necessary for understanding how farmers learn and develop new ideas.
- Many farmers are critical of existing public sector funded research for selecting, what they see as, irrelevant topics, and using small plot trials that are very different to the commercial context of farming.
- Scientists recognise this issue but reported that they are under pressure to publish in academic journals that demand the rigor derived from replicated plot trials.
- Farmers were also sceptical of results of research that had been funded by the private sector, particularly those developing technology and carrying out plant breeding.
- Four types of farmer-scientist interactions were identified:
    - Scientist managed research on farmers' land;
    - Farmers invited onto research stations;
    - Scientific monitoring of farmers' own operations;
    - Farmers' own research with researchers involved in providing ideas.

Implications:

- Farmers do experiment and adapt their farming systems to their ecological context using criteria that they feel are important. These approaches can be built on and harnessed by participatory approaches.
- While some farmers (and other agri-businesses) do have experiments that follow the scientific methods, others make holistic assessments using multiple criteria in a way that is not possible in a conventional, reductionist, scientific research. Farmers may set hypotheses explicitly before starting the experiment or they may use gut feelings and be experimenting without

acknowledging it. The scientific method, the holistic and the implicit approaches all have a contribution to make to participatory research.

- Farmers may not pursue scientific rigor and may change treatments during the experiment. Where rigorous detailed statistics are required, a more reductionist approach with greater researcher control may be needed.
- There is a range of key stakeholders who encourage farmers and agri-businesses to experiment with new ideas. Participatory research should work with these advisors, input sellers and crop buyers.
- Research questions and design should be decided with farmers and other agri-businesses to ensure they are appropriate.
- Participatory research can include different approaches with differing balances of control between scientists and farmers/agri-businesses depending on the type of information required. Best results are more likely to come when topics are addressed by combining farmers' own research with research on farms controlled and managed by scientists. Farmers have differing motivations to scientists and should not be expected to design, manage and collect data from trials that attempt to be statistically rigorous.

A further document (Annex 3) was produced that provided a set of interview guidelines and questionnaires that could be used to collect information from farmers and other agricultural related businesses concerning their involvement in developing new technology.

Between 1999 and 2003 EFORC trialled a range of cereal species and varieties with organic farmers throughout the south and east of England. The experiences from this work were used to develop approaches that can be tested or validated with existing groups of organic farmers. What was clear from the report of this work (Annex 4) was that the approach we had taken (using a relatively small number of farms [6], small plots and a wide range of varieties, species and mixtures) produced data that was difficult to draw firm conclusions from. This was due to the noise inherent within the system. It became clear that one approach to address this noise was to increase the sample size. However, the time input required to manage 6 sites and undertake full assessments made the suggestion of increased sample size untenable.

Building on the systems of existing farmer involvement and from discussions with the existing participatory farmers (Organic Arable Marketing Group, Organic Advisory Service advisors and the Elm Farm Organic Research Centre Arable Farmer Group) about what would be their solution to this issue (bearing in mind the financial and other constraints of the project), there was general agreement that wheat should be the species investigated and in particular winter wheat. From the experience of the research team and from the discussion held it was agreed that the basic experimental protocol must be simple, be able to be undertaken by the farmers with their own machinery and within the farmers' time constraints. A protocol (Annex 5) was established and reviewed each year at an annual post harvest project team review meeting

OBJECTIVE 2. COLLECT INFORMATION ON THE RANGE OF CEREAL VARIETIES CURRENTLY GROWN BY ORGANIC FARMERS TO HELP IDENTIFY THE MAJOR PRIORITIES AND CONSTRAINTS AMONG THE VARIETIES AVAILABLE.

Information on cereal varieties grown on organic farms was collected for the first year of the project. The main source of information was the Organic Arable Marketing Group (OAMG) who asked its members to complete a planting record each autumn and spring. In the first project year (autumn 2002), 35 farmers responded to the survey. In all, 13 winter wheat varieties were grown by the farmers, with the most commonly grown varieties being Claire (grown by 12 farmers) and Hereward (grown by 9 farmers). The areas of the varieties grown reflect this (Figure 1). It can also be seen that the area of mixtures grown is relatively large compared to the majority of the other varieties (Figure 1). It is interesting that many organic farmers are choosing Hereward, the oldest variety on the recommended list. It may be that, because of its age, it was bred under slightly less intensive conditions and, as a result, is more suited to growing under organic conditions.

The results of the OAMG planting returns were confirmed when talking to farmers involved in the project. The most commonly grown winter wheat varieties were Hereward and Claire, as it was generally felt that they performed reliably. It was also common for farmers questioned to be growing variety mixtures instead of pure stands. These mixtures often included Claire as a component.

Through further conversations with farmers, it was clear that one of their major concerns was the ability to achieve milling specifications with their winter wheat crops. It was felt that the specification for protein concentration of 13% (Dry matter basis) was particularly difficult to meet.

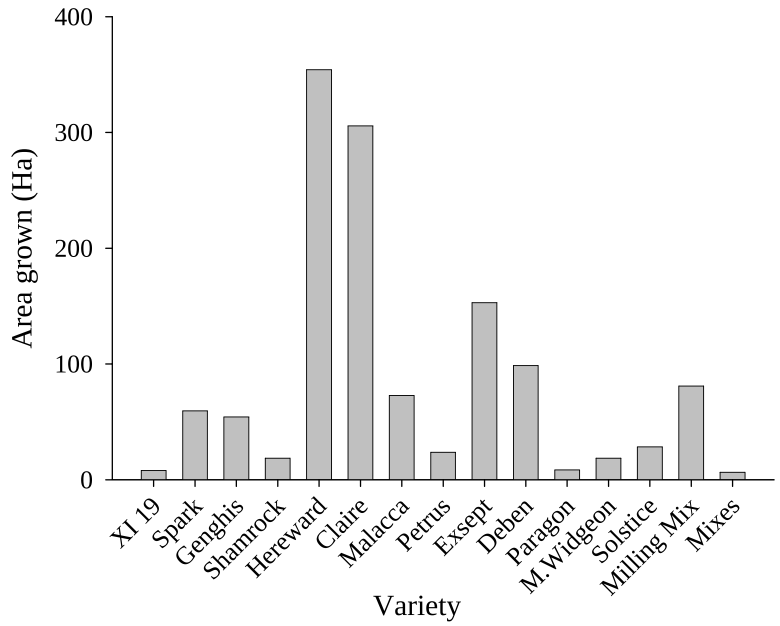

Figure 1: *Total areas (Ha) of winter wheat varieties grown by Organic Arable Marketing Group members in autumn 2002.*

OBJECTIVE 3. ESTABLISH A PILOT PROGRAMME OF CEREAL VARIETY TRIALS WITH ORGANIC FARMERS ON ORGANIC FARMS USING THE METHODOLOGY DEVELOPED BY OBJECTIVE 1.

This objective was met in full with two areas of additional work* added in the third year in response to the farmers'/advisors' requests. The three areas of work were;

- On Farm Variety Trials: The variety trialling was piloted on a small number of farms in year one and then rolled out to a large number in years 2 and 3.
- *Garlic Oil Treatment: Two sites were selected to trial the affect of a garlic oil seed treatment on crop performance.
- *Performance Benchmarking: Working with Abacus Organic Associates to collect and collate cereal performance data from a range of organic farmers.

Trials were established in year 2 and 3 of the project with up to 20 organic farmers in the East and West of England using the protocols established in objective 1 (Annex 5). The protocols were reviewed at the end of year 2 with the project team but also at a meeting of participatory farmers and organic advisors. There were limited changes made to the protocol.

ON FARM VARIETY TRIALS.

Approaches.
Approaches to this section of work are covered in Annex 5.

Results.
First year of variety trials (Year 2 of project)

Despite considerable complications for the farmers i.e. failed crops, harvesting difficulties etc we managed to collect data from 15 of the 20 sites.

Yield Survey
Yield data in Figure 2 shows the overall variability in yields from 15 sites with a 2.5 fold spread, from the lowest to highest; this variability is believed to be as 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.

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

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 out yields Hereward (HGCA 2006). 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% 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.

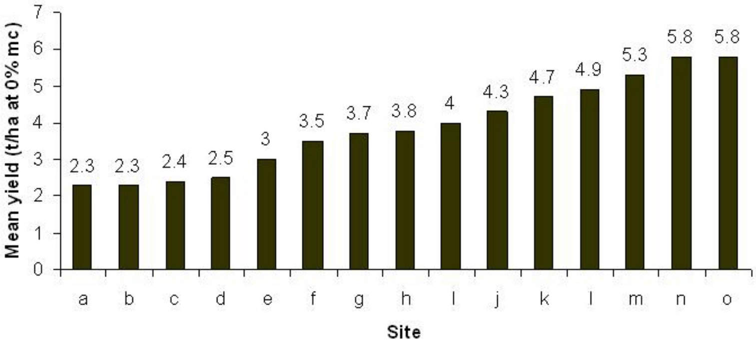

Figure 2: *Mean grain yield from successful harvests from 15 trial sites.*

Site	Yield range	Rank 1	Rank 2	Rank 3	Rank 4
A	0.8	M	S	H	X
B	0.6	S	H	M	X
C	1.0	H	X	S	M
D	0.9	X	S	M	H
E	*	*	*	*	*
F	1.2	X	H	M	S
G	2.3	H	S	X	M
H	0.8	S	X	H	M
I	1.1	H	S	X	M
J	0.2	X	M	S	H
K	1.1	H	M	X	S
L	0.9	X	M	S	H
M	1.8	M	X	S	H
N	2.1	H	S	M	X
O	0.7	H	M	S	X
All Sites	**3.5**				

Table 1: *Yield range (t/ha @ 0%mc) 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).*

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% dry matter. Among the varieties, the ranges of mean values were 212 to 245s and 8.5 to 9.1% 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.

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 (Wolfe, 2000). 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.

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 3). It is also apparent that “short” plants were on average higher yielding relative to “tall” plants (Figure 4). 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/geological differences between East and West might be important in determining height.

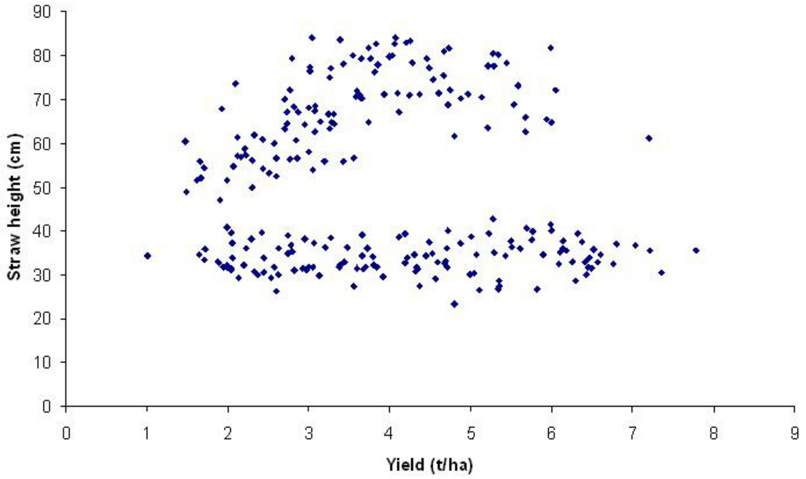

Figure 3: *Straw height against grain yield for all varieties at all sites*

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).

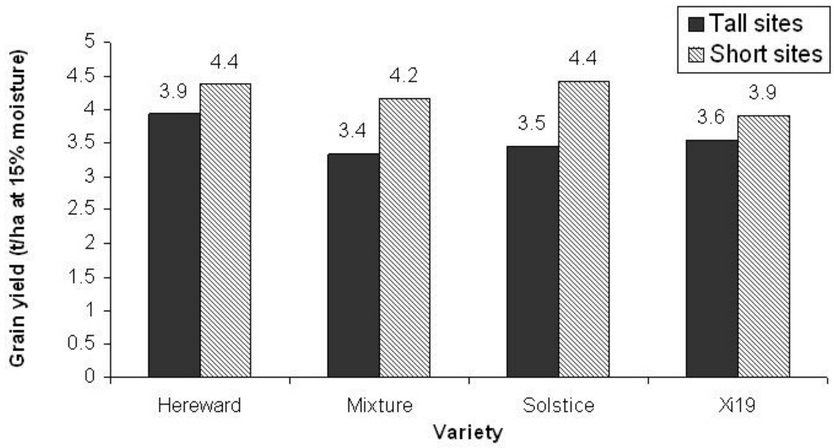

Figure 4: *Grain yield for varieties at “tall” and “short” sites.*

Higher mean yields at “short” sites could be attributed to a greater number of heads per unit area than at “tall” sites (Figure 5). 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 grains per ear or a lower thousand-grain weight at the “short” sites.

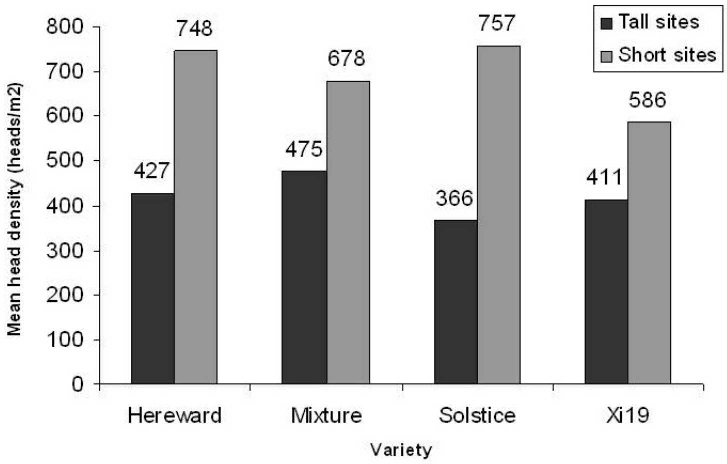

Figure 5: *Average number of heads per unit area for varieties at "tall" and "short" sites.*

Comparing the "tall" and "short" sites for total straw production showed that the "tall" sites produced more straw per unit area 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 6).

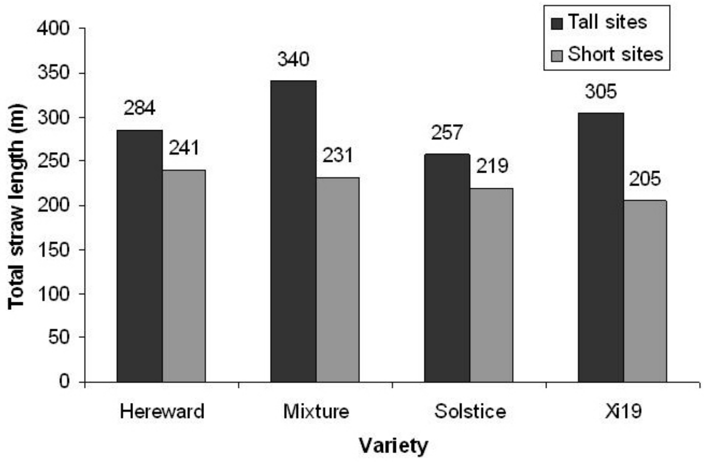

Figure 6: *Cumulative straw length (m per m^2) for varieties at "tall" and "short" sites.*

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 7). Confirmation of these observations was an open question for the following year's trials.

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.

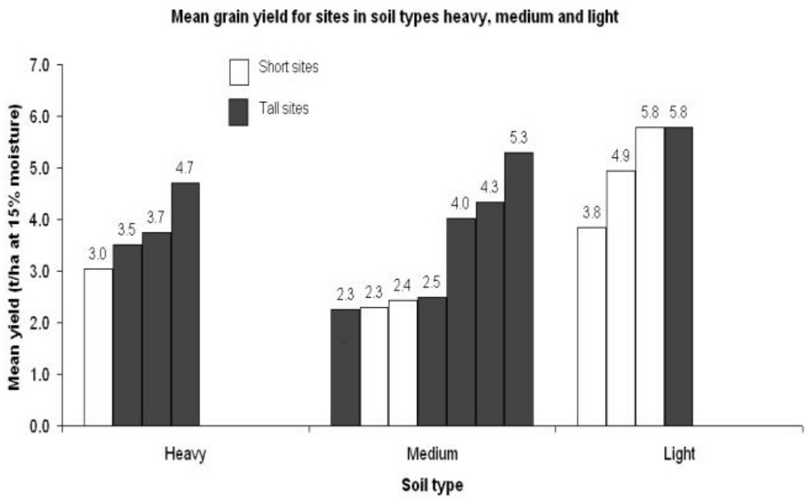

***Figure 7:** Mean grain yield for sites on heavy, medium and light soil types.*

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% 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.

Second year of variety trials (Year 3 of project)

In the second year of trials, seed was sent to 19 farmers. Despite drilling problems and predation, data was collected from 12 farms.

Yield
Yield variation among sites was larger than the difference between varieties; this is consistent with the results from the previous season. However, the overall average yield this season (5.60 t.ha^{-1}) was greater than in 2004 (3.9 t.ha^{-1}) (Figure 8).

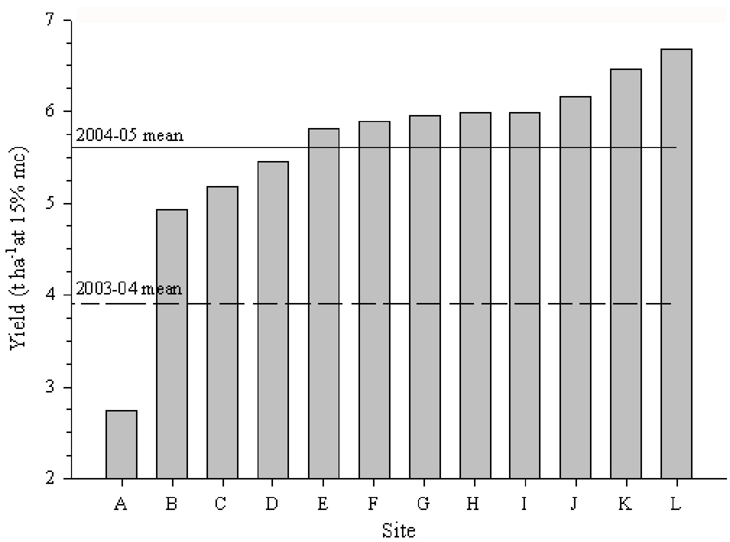

***Figure 8:** Average 2004-05 yields of the three varieties and mixture at each site (LSD=0.66) and the means of all yield data in 2004-05 and 2003-04.*

Yields at most sites ranged from 4.9 to 6.7 t ha^{-1}, with the varieties at just one site averaging < 3 t ha^{-1}. This was probably a result of late drilling the previous autumn because of the bad weather.

There was no significant difference between yields of the varieties and mixture. However, there was a significant (P < 0.01) interaction between site and variety; this means that the relative performance of the varieties differed at different sites as was also seen in year 1.

Site variation: short/tall straw

The results from the first year of trials (above) revealed an East/West split across the country; the wheat in the West was shorter but higher yielding, compared to the taller and lower yielding wheat in the East. In contrast, in 2004/05 the wheat grown on the western sites was significantly (P < 0.001) taller than on those in the East (77.6 cm and 70.1 cm in the West and East, respectively), although the differences were not as large as in 2003/04. The eastern sites also seemed to be lower yielding than the western sites, but this was due to the low yields at site A (Figure 8), which affected the overall average for the eastern sites.

Quality

Quality results from participatory farms have revealed an increase in HFNs and specific weights on the previous season to over the threshold required by millers, but also a decrease in percentage protein concentration.

As with the yield results, the largest differences in the grain quality parameters thousand grain weight (TGW), specific weight, HFNs and protein were found among sites (Figure 9). However, there was also a significant difference in specific weight among varieties (Table 2), and a significant interaction between site and variety found in the TGW results (i.e. the relative TGWs of the varieties differed among sites).

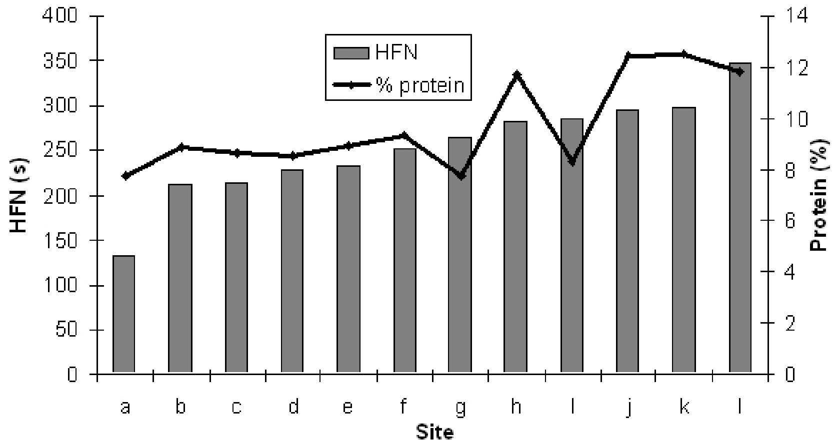

Figure 9: *Mean quality parameters for all sites 2004/05.*

Although there were no significant differences among the HFN results of the varieties, on average HFNs were higher in 2004/05 than the previous season (Table 2). The low HFN results in 2003/04 can be attributed to the wet summer causing grain to sprout and HFNs to drop.

	Hagberg Falling Number (s)	Protein (%)	Thousand grain weight (g)	Specific weight (kg/Hl)
Hereward	240	10.2	44.8	79.5
Solstice	256	9.5	45.1	79.7
Xi 19	279	9.5	47.3	76.3
Mixture	248	9.7	45.3	78.7
Mean 2004/05	**256**	**9.7**	**45.6**	**78.5**
l.s.d.	49	1.5	0.22	0.9
Mean 2003/04	**226**	**12.0**	**49.8**	**71.9**
l.s.d.	11	0.6	2.53	0.7

*If the difference between means is greater than the l.s.d. then it is a significant difference.

Table 2: *Quality results of varieties in 2004/05 compared to the overall mean in 2003/04*

Unlike the HFN results, the average percentage protein was lower in 2004/05 than 2003/04 (Table 2). However, if the protein harvested per hectare is calculated using the yield results, it can be seen that the yield of protein per hectare increased by 16% (0.06 $t.ha^{-1}$) between 2003/04 and 2004/05. The reason that the protein percentage fell between the two years was because the carbohydrate in the grain increased by a greater proportion (47%). This confirms that the weather difference between years affected more the carbohydrate producing potential of the crop rather than the protein producing potential because the latter is much more dependent on available soil-bound nitrogen. Also, the nitrogen scavenging ability of the modern wheat is not as effective as the carbohydrate producing mechanisms.

Most of the varieties achieved the milling requirement for HFN (>250s) and all made the requirement for specific weight (>76 kg/Hl); an improvement on the previous season. However, in common with last year, none of the varieties met the protein level required for a milling premium (>13%), and, in fact, protein contents were lower in 2004/05 than 2003/04.

Conclusions.

Data from both cropping years showed significant differences, among sites for grain yield, percentage weed cover, cumulative straw length, HFN and TGW. Differences between varieties were not significant for these traits. This highlights the importance of breeding varieties adapted to, and adaptable to organic systems.

Straw height and ear density showed a significant difference for both sites and varieties, but not their interaction. These are characters of the individual varieties. Ear density was significantly greater in the West than the East.

These results highlight the variability of organic systems and the difficulty of achieving protein concentrations required by millers among conventionally-bred varieties grown under organic conditions.

GARLIC OIL – ON FARM TRIALS.

After the first year of field trials, farmers and advisors involved in the project were invited to a meeting to talk about results. In response to farmers'/advisors' request work was undertaken to investigate the effect of garlic oil seed treatment on crop performance. A similar participatory approach was taken with including garlic oil as a seed treatment within the trials. Two farms that were experienced in undertaking trials were selected and were provided with additional seed lots to be incorporated within their participatory variety trials.

Garlic oil had limited impact on the crop. Establishment results indicated no early benefits from the garlic oil treatment (Figure 10). Grain yield from garlic oil treated seed was highly variable relative to other varieties and between the two sites.

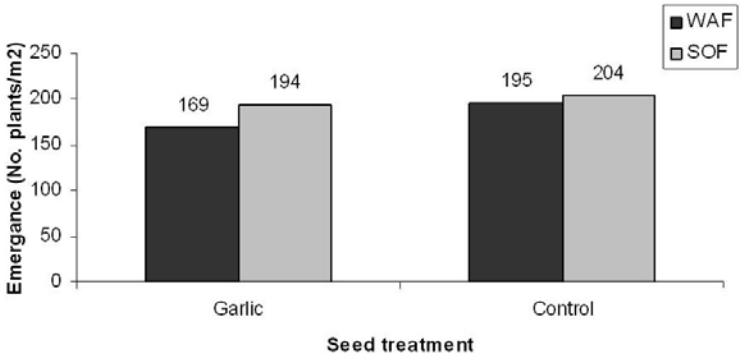

Figure 10: *Emergence for Hereward with and without garlic oil seed treatment.*

PERFORMANCE BENCHMARKING.

After the first year of field trials, farmers and advisors involved in the project were invited to a meeting to talk about results. Feedback from those present included a suggestion that, as well as having results from the participatory trials, it would be useful to carry out a benchmarking exercise. It was thought that this would then provide information about more varieties over a greater number of farms in different areas of the country.

A form was drafted which an advisor could take round on routine visits to farmers. Farmers completed the forms with information about varieties harvested the previous season. They were asked about the farm soil type, varieties grown, previous cropping, yields, grain quality and the value of the crop, amongst others.

Unfortunately, advisors were unable to collect as much data as initially thought, and, in all, data from 24 farms were collected. However, many of these farms did provide information on several varieties. There were also problems in collecting complete datasets. Although yields were usually recorded, grain value and grain quality parameters such as protein concentration and Hagberg falling number were either not known or not given.

Below are the average yields of the varieties recorded in the survey (Table 3). It is sorted in yield order, with Exsept yielding the highest and Xi 19 the lowest. However, it can also be seen that the number of data points for each variety varies considerably, calling into question the accuracy of the yields.

Variety	Number of Samples	Average yield (t ha^{-1})
Exsept	6	6.17
Nijinsky	5	6.06
Chablis	8	5.76
Istabraq	5	5.72
Claire	13	5.70
Deben	6	5.45
Amaretto	6	5.06
Gladiator	5	4.88
Hereward	13	4.71
Paragon	19	4.46
Okostar	8	4.31
Ego	3	4.28
Malacca	1	4.20
Petrus	2	3.96
Sokrates	10	3.90
Xi19	2	3.09

Table 3: *Average yields of varieties in the benchmarking exercise.*

Table 4 compares the yields produced on different soil types. As expected, the crops grown on silts yielded the highest and those grown on sandy soils the lowest. However, again there were considerably fewer samples in one category (silts).

Soil type	Number of samples	Average yield (t ha^{-1})
silts	14	7.27
clays	51	5.17
sands	32	3.89

Table 4: *Average yields produced on different soil types in the benchmarking exercise.*

It was concluded that, although benchmarking could be a very useful tool, many more samples would be required to paint an accurate picture of organic wheat yields and the relative performances of varieties.

OBJECTIVE 4. TO OBTAIN INFORMATION ON WHICH SEED-BORNE DISEASES, INCLUDING ERGOT, MAY CAUSE PROBLEMS IN THE ORGANIC SEED PRODUCTION CHAIN OF WHEAT, BARLEY, OATS AND TRITICALE, AND TO EXAMINE ANY RELATIONSHIP BETWEEN ORGANIC HUSBANDRY CONDITIONS (SEED RATE, SOWING DATE, ROTATION ETC) AND INCIDENCE/SEVERITY OF DISEASE.

Seed health tests were carried out according to standard protocols using conventional techniques. Briefly, these were agar plate tests for *Micodochium nivale* (seedling blight on wheat and oats) and seed washing for removal and quantification of *Tilletia caries* spores (bunt on wheat). Embryo extraction and examination for loose smut was used for both wheat and barley. *Pyrenophora graminea* (leaf stripe) and *Pyrenophora teres* (net blotch) on barley seed were assessed on agar plates. Seed washing was used to determine infection by loose and covered smut on oats. Occasional incidence of other seed-borne diseases was observed and recorded in agar plate tests.

Samples of seed were obtained in harvest years 2002, 2003, 2004 and 2005. Sources were “as grown” seed being multiplied by organic seed producers for eventual certification, “farm-saved” seed from organic growers sent in for commercial testing, seed samples sent in from participatory variety trials carried out as part of OF0330, and samples from organic variety demonstration plots coordinated by Abacus Organics. A total of 676 samples were examined. The majority (420) were wheat to reflect the focus of the project, but 100 barley samples, and 106 oat samples were also examined, as well as 50 triticale samples.

All samples examined would have been grown from untreated mother seed to meet the requirements of organic production. In the case of farm-saved seed, or seed from variety trials, samples were more likely to have been derived from two previous untreated generations, though it was not possible to obtain traceability on all samples. Seed-borne diseases such as loose smut, bunt, and leaf stripe, depend on multiplication through seed generations, whereas seedling blight is dependent on seasonal conditions, and the availability of external inoculum sources.

The majority of samples tested met established treatment thresholds for non-organic seed. Treatment thresholds for wheat seed have recently been extensively investigated and revised, producing a safe level below which seed could be sown untreated. Provided organic seed reaches these standards, it can be used for crop production, and results show that most samples had higher health status than the conventional treatment thresholds. However, there were occasional problems, most notably in the case of bunt on wheat, where very high levels of infection were seen, and the seed would have been unsuitable for further multiplication as seed, or for ware production. It was not possible to relate these occurrences consistently with any particular farm practice, with the possible exception of one site where minimum tillage was used, and the crop was always a second wheat. Under these conditions, an initial bunt problem introduced on seed might perpetuate from year to year. Other instances of high bunt infection were anecdotally associated with year-on-year seed saving, and no health checks, but the origin of the infection could not be determined.

Over the four years of testing, there was no indication of increasing problems with the main seed-borne diseases, and no indication of the emergence of “minor” diseases such as covered smut. One sample of barley was severely infected with foot rot (*Cochliobolus sativus*) which can affect establishment, but this appeared to be related to a single variety, and was not recorded again. Ergot (*Claviceps purpurea*) was present at high levels (e.g. over 50 pieces per kg of seed) in several samples, but ergot infestation has been increasing in frequency and severity in conventional production recently. *Microdochium nivale* sometimes reached high levels on wheat seed in seasons favourable to the disease, but similar levels were also seen in conventional samples received for commercial testing at NIAB.

Despite the overall high health status of the samples tested, it was clear that problems could occur. Bunt represents one of the most serious disease threats to organic wheat as whole crops may be lost. Occasionally, commercial C1 generation seed lots with comparatively low levels of infection, just above the treatment threshold, were found, and in these cases, merchants withdrew them from further organic production. Testing and removal of infected lots has undoubtedly contributed to disease free seed later in the production chain. However, it can result in the loss of valuable seed, possibly delay the introduction of new varieties, and in extreme situations, could limit the overall supply of organic seed.

Organic seed is defined as seed which is produced from a crop which is grown organically, but source seed may still be treated with conventional products during the early multiplication generations. The extent to which true organic breeding and seed production will affect seed-borne disease is not known. The availability of acceptable seed treatments, or the introduction of stable resistance to damaging seed-borne diseases, would provide the safeguards needed.

Full data sets for all seed testing are given in Annex 6.

OBJECTIVE 5. DETERMINE WHETHER CULTIVARS WITH GOOD POTENTIAL FOR ORGANIC PRODUCTION ARE RESISTANT TO ONE OR MORE OF THE SEED-BORNE DISEASE PROBLEMS.

Tests were carried out in two years, on wheat, barley and oats. Organic Seed Producers (OSP and others) were consulted on a range of appropriate varieties to include in the tests. Methods are described in Annex 7. Of the varieties tested, there was evidence of a high degree of "resistance" to bunt in the varieties Hereward and Solstice in each of the two years. The nature of the resistance is not known, and it may reflect disease escape rather than tissue resistance. Nevertheless, this finding indicates that there is some potential for breeding characteristics in wheat which reduce the chances of infection by seed-borne bunt.

One winter wheat variety, Exsept, was consistently more resistant to *Microdochium* in the ear than other varieties, but results were more variable for other varieties – e.g. Clare and Deben were more resistant in one year only.

The winter wheat varieties Exsept and Xi 19 exhibited high levels of infection for loose smut in both embryo and 2004 "growing-on" tests; Claire, Deben and Nijinsky appeared to be more resistant. All winter barley varieties were susceptible to loose smut; and for spring barleys, Optic appeared slightly more susceptible than the other varieties tested, though levels overall were very low.

Some tests to determine possible resistance to ergot were carried, though methods were not fully developed during the course of the project, and more detailed work in an ongoing LINK project (SAL 219) should provide more comprehensive data and methodologies.

Results for variety work are given in Annex 8. There has been little targeted breeding effort for introducing resistance to seed-borne diseases since the introduction of routine seed treatment for conventional production, so it is perhaps not surprising that the levels of resistance seen were not high. Nevertheless, it should be possible to introduce resistance for diseases like loose smut, though the occurrence of races in this pathogen makes the breeding process more complex.

OBJECTIVE 6. WORKING WITH FARMERS (OBJECTIVE 1), REVIEW AND IDENTIFY A RANGE OF ORGANICALLY ACCEPTABLE SEED TREATMENTS AND PROCESSES, CONSIDERING BOTH CHEMICAL AND PHYSICAL METHODS, AND TEST THESE UNDER ORGANIC CONDITIONS TO DETERMINE EFFICACY.

Seed treatment trials were carried out in 2004 and 2005. Products and processes selected for evaluation were based on a desk study carried out in the first year of the project (Annex 9), and comprised examples of biological, micronutrient and physical treatments. Several of the products (e.g. Garlic extract, EM1) are currently available for agricultural and horticultural use, and would be appropriate for organic systems according to consultations with the Soil Association during the course of the project, though none of the products tested were sold specifically as seed treatments. Trials with infected seed wheat and barley in the first year, and wheat only in the second year, were carried out at NIAB, Cambridge under non-organic conditions. Though this prevented an evaluation of potential beneficial effects of organic soils in suppressing seed-borne diseases, the dangers of introducing untreated controls within experiments on organic soils are significant, particularly in the case of a disease like bunt.

None of the treatments tested suppressed loose smut or leaf stripe on barley. None of the treatments used in 2004 significantly improved establishment (plant counts) when wheat seed had a high level (30%) of *Microdochium nivale* seedling blight, and none significantly increased final yield. In 2005, one of the biological treatments tested (from Crompton Ltd) did significantly improve plant establishment (145 plants/m^2 compared to 113 plants/m^2 for untreated plots, and 143 plants/m^2 for Sibutol, the conventional control treatment), though effects on yield were non-significant. Both biological products (Cerall and the Crompton product) suppressed bunt in 2005, as did Radiate (ammonium and zinc ammonium complex), though the latter had no significant effect in 2004. The hot air treatment also reduced bunt in 2005, though the effect was less marked in 2004. Results for bunt are summarised in the Table 5 below. Other data from seed treatment trials is summarised in Annex 10.

Though the mechanisms of action of some of the effects on bunt which were observed are not understood, it did appear that some biological treatments had benefit in reducing the disease. Applied spore loadings (2000 spores/seed) were high, and though such levels have been observed in organic seed, retrieval by seed treatment should probably not be attempted. At lower spore loadings, the effect of biologicals may be efficient enough to retrieve an infected seed lot. Hot air treatment also appeared to be partially effective, and, though no attempt was made to optimise the treatment process within this project, the viability of seed, plant establishment, and final yields, were not reduced by the 30s treatment length. Work elsewhere (Anders, 2004) has greatly improved heating processes and achieved a high degree of control of bunt, without loss of germination, and of the treatments and processes tested, this would appear to offer the greatest potential for reliable use.

Treatment	Bunted ears/plot 2004	Treatment	Bunted ears/plot 2005
Untreated	36.7	Untreated	28.5
Sibutol	0	Sibutol Secur	0
Radiate	32.7	Radiate	7.3
NMS	35.3	Cerall	7.5
EM1	42.0	Crompton	8.5
EM1 + micronutrient	48.7	30 secs hot air	9.8
Tricet Micronutrient	43.3	60 secs hot air	18.8
Bacillus subtilis	38.7	90 secs hot air	14.8
Garlic	35.3		
Hot air (90 secs)	27.3		
Lsd (p=0.05)	8.48		10.13

Table 5: *Bunted ears per plot (12m) counts in seed treatment trials, 2004 and 2005.*

Seed cleaning was investigated as a means of improving establishment in *Microdochium* infected wheat. Gravity separation was carried out on behalf of the project by CYO Seeds on a seed lot with 30% infection. Though establishment counts and early spring counts were improved slightly in the cleaned seed compared to uncleaned, effects were not significant, and final yields were not improved. Incidence of disease in the cleaned versus uncleaned seed (% infection on agar plates) was similar, indicating that the process, although removing light and shrivelled seed, did not selectively remove infected seed. However, with higher levels of *Microdochium*, which can occur in some seasons, cleaning may reduce disease incidence as the proportion of infected, shrivelled seed also tends to be higher (unpublished observations).

OBJECTIVE 7. FORMULATE A CODE OF BEST PRACTICE FOR THE PRODUCTION OF CERTIFIED ORGANIC SEED, AND FOR THE PROCESSING OF SEED ON ORGANIC FARMS.

This objective was carried out in conjunction with other NIAB work from other projects. It concentrates on minimising bunt, the single most important problem found in this project. It also contains references to two HGCA publications, which all levy papers should get free of charge

CODE OF BEST PRACTICE FOR ORGANIC SEED PRODUCTION. (also Annex 11).

During the four years of organic seed testing within this project, there was no indication of emerging seed-borne disease problems. However, there were sporadic incidences of serious levels of seed-borne disease, and in these cases action was necessary. The most serious problem was the occasional occurrence of bunt in wheat seed, and because of this, the major focus of these suggested guidelines is to minimize the chances of bunt increase, but attention should also be paid to other diseases which may occasionally affect the quality of seed.

Reducing the risk of bunt

- Always test any untreated “mother” seed. Effective sampling guidelines have been established, and are published in the HGCA Fact Sheet No 72, (sent to all HGCA Levy Payers or available from the HGCA website)
- For seed which is destined for further multiplication, the desired standard for bunt is as close to zero spores/seed as possible, but in any case, below 1 spore per seed.
- For seed which is destined for crop production, and not for further seed generations, including farm-saved seed, levels of infection should not be higher than 1 spore per seed.
- Where it is intended to farm-save seed of wheat, crops should be first wheats if possible, since the most consistent bunt problem observed was associated with minimum tillage and second wheat production. It is possible that soil-borne bunt could survive in this situation, and perpetuate a low level of bunt in a particular area, which could increase quickly in a crop
- For farm-saving, always keep grain intended for seed separate from ware
- Some varieties tested were either resistant to bunt infection, or escaped infection. However, in the absence of ongoing information on varieties used for organic production, it is not yet possible to rely on variety resistance as a means of control.
- Some seed treatments and treatment processes showed promise for the control of bunt in this work, but in the absence of commercially available systems and recommendations, seed producers and growers farm-saving seed in the UK still need to rely on stringent seed health using the standards recommended.

- Wheat seed sown relatively late (November/December) tends to be more prone to bunt infection as emergence is slowed. In cases where growers wish to use seed just above the threshold level of 1 spore/seed, early sowing will help to minimize any chances of infection; however, the aim should be to avoid using such seed.

Guidelines for using untreated seed in conventional agriculture are summarized in the HGCA Publication "Wheat Seed Health and seed-borne diseases" (Price £10, or free to HGCA Levy Payers). Though aimed at conventional agriculture, the principles described are also relevant to organic production, and if adhered to, will minimize the risks of seed-borne diseases developing in organic seed stocks.

OBJECTIVE 8. TO EVALUATE THE PARTICIPATORY RESEARCH AND DEVELOPMENT APPROACH THROUGHOUT THE ENTIRE RESEARCH PROCESS AND PRODUCE GUIDELINES AND MATERIALS FOR BEST PRACTICE. DATA WILL BE COLLECTED THROUGHOUT THE DURATION OF THE PROJECT.

During the project the participatory process was assessed on an on an ongoing basis. Three annual monitoring and evaluation exercises were carried out, in which interviews were undertaken with farmers and researchers participating in the project. Annex 12 reports on the findings of this work. The outcomes of the yearly studies were discussed at the post harvest project meetings and where possible recommendations were incorporated into the following years' approaches. The conclusions of the study were:

Most members of the team agreed that the project was harder than anticipated. Harder in terms of the new skills needed, the learning curve, and also the time demanded. The best insight from one of the team members is summarized in this set of comments:

- Farmer participation is essential to ensure relevance of objectives
- Difficulties in farmer experiencing lack of ownership – this is improving, but very difficult with restricted time budget.
- Different farmers expect/require different levels of participation
- We should aim to build on these relationships that we have established for mutual benefit in future projects
- Main problem is lack of spare time farmers have – or, more importantly, how they prioritise this time.

Overall, the conclusions of the research team were that:

- Farmers and researchers have different ideas about how to work together.
- It is difficult to communicate our needs and understand theirs
- Farmers are particularly difficult to engage
- We need to shift the emphasis from problem solving to dialogue
- The power to set agendas needs to be addressed
- Farmer Participatory Research (FPR) is either useful for research (if it has a clear aim) or empowers farmers
- It is more time consuming and expensive than envisaged.

Returning to the key points from the Defra call:

- Relevance: Enhancing the direction of the research programme
- Dissemination: Transferring information into farming practice, encouraging effective knowledge transfer to a wider group than those participating in the project
- Quality: the need for scientific rigor should not be compromised
- Reflection: Evaluation of the performance of the participatory approach

We can conclude that the project has involved farmers in the process, and while addressing one of their concerns, perhaps did not address their highest priority concerns. However, the relationships developed with farmers, the feedback from them, can be used to further focus the direction of the research programme, and bring the research agenda into line with farmers' needs. The project has encouraged farmers to question issues and feed ideas into their own research. The structured nature of the proposal did not allow for this form of research to be integrated and used.

The dissemination stage of this project has been completed with farmer events and trade press articles in the 3rd and 4th year of the project (see Knowledge Transfer below). This included engaging farmers with the results, and with the idea of farmer participatory research. The results of the project (the process, and the results) have been presented to a wide range of audiences already, from organic farming groups, to international conferences, farmers, and academics in the UK. The lessons learnt from the project have also been integral in the establishment of the WheatLINK project.

The challenge of maintaining scientific rigour while involving farmers more in the research process has been difficult. As the project progressed, we realised that greater involvement of farmers from the beginning, and greater communication between all partners in the research concerning aims, needs, research methods, and outcomes, would have done much to facilitate this.

Finally, this research has shown that adopting the participatory approach for use in the organic farming sector is more complicated than first envisaged. The research team has learned much, and if lessons learned from this project are taken into consideration in further research, then it will be possible to improve the performance of the participatory approach. Key issues are:

- Acknowledging and addressing the training needs of farmers and researchers at the outset of a project
- Building a team of people (farmers and researchers) who understand each others' background, and are able to work together towards an agreed set of goals.
- Appreciating the commitment farmers must make on top of their existing workloads to engage in this sort of activity, and doing what is possible to facilitate this.
- Identifying appropriate people to act as boundary spanners and draw all stakeholders together in dialogue.
- Within this framework, identifying research goals that can be realistically met by all concerned.

Materials for best practice have been produced in three formats of increasing complexity. The first is a double sided A4 flier (Annex 13) that can be provided to farmers/researchers that sets out in very basic terms what is involved in taking part in research. This is supplemented by a longer document (Annex 14) that goes into more detail outlining the pros and cons and the expectations of all partners in this type of farmer participatory research. The final is a detailed compendium for those who wish to have more details on the participatory process (Annex 15).

OVERALL DISCUSSION AND CONCLUSIONS.

This project was established to investigate methods of participatory research that could be useful in a UK context with the research team involving both natural and social scientists. Throughout the project opinions between the natural and social scientists have differed and it has not been possible within the time frame of the project or the writing of this final report to come to consensus. Therefore, it was decided that each group should come to their own conclusions.

SOCIAL SCIENTISTS

The experience of working together in a team which brings together people from diverse disciplinary backgrounds and research experiences has been thought provoking. In an attempt to bring together all of our different areas of expertise, we have all been challenged to justify our beliefs (even prejudices), and in particular, to reconsider how we feel about some of the key debates: the value of natural versus social science approaches to research, the value of quantitative and qualitative data, and the merits of farmer participatory research or the separation of scientific research into a more controlled arena (e.g. on station), and whether the outcome, or the process of obtaining the outcome, is the most important aspect.

The attempt to develop participatory research approaches was challenging from the onset, as the demands for writing a proposal within a short-timeframe, against a specific call for research, go against the participatory ethos of collaborative research developed through ongoing consultation with farmers. The current system of funding does not support the formation of a research team (of researchers and farmers) and input of farmers into a proposal. Furthermore, the requirements for funding (plan of activities, and more importantly, rigorous budget) inhibit reflexivity in the research: it is difficult, if not impossible, to respond to farmers' input concerning research priorities, or alter research plans as a consequence of one years' results.

Within the project team, their remains a core debate concerning the ability of farmers to be involved in research, and the role of farmers, scientists, on-farm work and research stations in agricultural research. It is difficult to assess whether on farm or on station work is more cost effective. Each requires such different resources, in terms of staff skills (completing agricultural tasks, or facilitating farmers' involvement), and basic costs.

On farm work can appear to be more time consuming, and therefore more expensive. However, the hidden overheads of ownerships and maintenance of research stations (including agricultural equipment) mean that the full cost of on-station trials is high too. Each is a very different type of research, and in reality, each is appropriate to different types of study.

Participatory work relies on farmers who are willing to carry out research. Currently, in the UK, all are unpaid volunteers. Thus, they are a self-selecting group, generally comprised of those who have the interest, and are prepared to donate time, to see research happen on their land. Some farmers are very keen on research, others are interested, but perhaps do not have the time or money to run trials. They might limit their role to identification key research questions, and perhaps contribute to the evaluation of results. Others might also help discuss the trial design. Hosting a trial, and ensuring treatments are carried out precisely, and measurements taken at appropriate times, requires a much bigger time input. If research was moving off station and onto farms, it would be realistic to pay farmers for the time they spend managing the trial, which would otherwise be spent paying for staff on the research station. In effect, it is outsourcing the agricultural labour involved in a trial.

Within the post-project period, there has been discussion of who is most qualified to design experiments. This raises the broader issue of who is better able to identify key issues, set research priorities, design research experiments, evaluate outcomes, analyse results, and determine conclusions? Perhaps what is missing here is the appreciation that we are all working towards the same goal, and that rather than being at loggerheads, it would be more appropriate to work in partnership, with mutual respect for each others' expertise. A broader perspective, in which individual projects, and roles within projects, are seen as being connected into a wider programme of research, would perhaps facilitate this. Within a broader perspective, there would be a role -for farmers and scientists in problem identification,

- for farmers and scientists to monitor experiential learning on farms, and identify issues arising form this which might merit further investigation
- for scientists (disciplinary experts) to carry out basic science under controlled conditions (on station) to identify key biophysical relationships
- for farmers and scientists to test out new farming techniques / farm management scenarios on farm
- for farmers to adapt new developments in farming to their particular farmholding – its land and its business characteristics.

Overall, it is not a case of what is best, but what is most appropriate for which situation, and how all can contribute. The varied research approaches discussed are complementary, not competitive. A farmer participatory approach, whether in consultation or in full involvement, is necessary to ensure that the fields within agricultural science are not separated from their beneficiaries.

NATURAL SCIENTISTS

The project had dual purposes to develop a participatory research methodology with UK farmers and within this framework to develop seed production and variety trialling protocols.

The project has shown some success at variety trialling with some differences in some traits. However, due to the inherent variation within organic systems and the varieties that we investigated it proved impossible to identify whether one variety would be more successful than another for all farms and farmers. What has been learned from the experience is that a large number of sites/participants are needed.

Results from seed health tests were generally positive, with few samples showing levels higher than the treatment thresholds used for conventional production. Where problems were found, the disease present was generally bunt. However, there was some evidence that the cultivars Hereward and Solstice had some level of resistance to this disease, although the mechanism wasn't clear. Unfortunately, despite there being some positive effects in terms of plant establishment, none of the potential organic seed treatments affected yield.

The real challenge of this project was to work effectively within a multidisciplinary team including social and agricultural scientists and farmers and the seed industry. The difficulties in working in a multidisciplinary environment were clear within the project with communication proving difficult in the early stages and both researchers and farmers finding it difficult to engage and understand the project. This communication issue was a major one. Meetings and conversation were had in the early parts of the project where discussions were had but communication had not occurred effectively. We each went away with a different understanding. There were also many staff changes in the early parts of the project (this was unfortunate but probably not unusual in these days of contract research work and uncertainty in peoples careers). However, as the "team" stabilised and built on their relationships the communication, trust and therefore the project improved. What became evident from early on in the project was that the amount of staff time needed to engage with the farmers had been seriously underestimated. The farmers wanted more contact and support from the researchers which was not possible within the project funding and difficult to justify from the agricultural scientific point of view although the social scientist would fully justify it. What has been learnt is that communication and managing expectations of the work is critical for successful engagement of partners and project.

It is unlikely that farmer participatory research is ever going to be a cheap option for all types of research. There is a spectrum of farmer participatory research which can be utilised and be very successful as long as the work being undertaken is appropriate to this approach. For example, rigorous multifactorial experiments are unlikely to be financially viable or scientifically a success using farmer participatory research. However, engaging farmers in identifying the issues and then monitoring the resulting work to ensure relevance to the farming situation and ability to be taken up is important. Towards the other end of the spectrum farmer participatory research can be used successfully where a more applied and functional objective has been set. Variety trialling fits in this area.

Although farmer participatory research can be used in publically funded research it is often not appropriate for complete projects. The work in agri-environment areas is often a long way from the market or application on farm or is being funded for different reasons than farmers' needs. This work often needs to be scientifically rigorous and statistically analysable which is often difficult and expensive using farmer participatory research. This does not mean that farmer participatory research does not have a place in setting out what research should be commissioned in this area. Defra recently commissioned a consultation exercise with organic stakeholders (OF0350) which engaged farmers and other organic stakeholders to identify research aspirations. This project was used to identify research priorities but not research methods.

Farmer participatory research also has a place in publically funded research. The LINK funding scheme is obviously a route where farmers can be pivotal in identifying and driving the research within a project. However, in other projects within Elm Farm Organic Research Centre we work with farmers and plant breeders to ensure that the work we are undertaking is relevant and can be easily communicated to end users.

It is difficult to assess whether the project was a success. It has identified some interesting and useful agricultural science findings and there has been some success in working participatory. A start of participatory methodology has been developed and the best practice documents created. How useful these will be has to be seen. What is clear is that this methodology is not a one size fits all or an easy option. The naïve view that the successful models used in Southern agriculture could be lifted into the UK has been disproved. The UK farmer is supported in so many other ways from that research is not seen as critical as it is in the South. The comment received by researchers within the project from farmer participants "that they were doing EFORC a favour" is both critical of our ability to fully engage them in the project process but also their views on research. However we have also seen after several years undertaking work with specific farmers them beginning to use the research that is of benefit to their systems.

Further work
There are several aspects of this project that would warrant further investigation. These include:
- The variability of organic systems.
- The relationships between different academic disciplines.
- The economics of participatory versus traditional research methods.

FIGURES.

Figure 1: *Total areas (Ha) of winter wheat varieties grown by Organic Arable Marketing Group members in autumn 2002.*

Figure 2: *Mean grain yield from successful harvests from 15 trial sites.*

Figure 3: *Straw height against grain yield for all varieties at all sites*

Figure 4: *Grain yield for varieties at "tall" and "short" sites.*

Figure 5: *Average number of heads per unit area for varieties at "tall" and "short" sites.*

Figure 6: *Cumulative straw length (m per m^2) for varieties at "tall" and "short" sites.*

Figure 7: *Mean grain yield for sites on heavy, medium and light soil types.*

Figure 8: *Average 2004-05 yields of the three varieties and mixture at each site (LSD=0.66) and the means of all yield data in 2004-05 and 2003-04.*

Figure 9: *Mean quality parameters for all sites 2004/05.*

Figure 10: *Emergence for Hereward with and without garlic oil seed treatment.*

TABLES.

Table 1: *Yield range (t/ha @ 0%mc) 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).*

Table 2: *Quality results of varieties in 2004/05 compared to the overall mean in 2003/04.*

Table 3: *Average yields of varieties in the benchmarking exercise.*

Table 4: *Average yields produced on different soil types in the benchmarking exercise.*

Table 5: *Bunted ears per plot (12m) counts in seed treatment trials, 2004 and 2005.*

ANNEXES.

Annex 1: Identification of Participatory Research and Development Methodology for Research into Organic Cereals. Literature review and working document.

Annex 2: Existing systems of farmers and agri businesses' involvement in organic cereals research.

Annex 3: Monitoring forms documenting the views of farmers, other agricultural related businesses, and scientists.

Annex 4: Organic Cereal Variety and Variety Mixture Trials 1999 – 2003.

Annex 5: OF0330 Farmer Participatory Research Protocol.

Annex 6: NIAB Organic Seed Disease Data.

Annex 7: Methodologies for evaluation of resistance to seed-borne diseases.

Annex 8: Cultivar resistance data.

Annex 9: Review of Potential Seed Treatments for Use in Organic Cereals.

Annex 10: Seed treatment data.

Annex 11: Code of Best Practice for Organic Seed Production.

Annex 12: Cereal varieties for organic production: Developing a participatory approach to seed production and varietal selection. An evaluation of the participatory process.

Annex 13: Short best practice document.

Annex 14: Long best practice document.

Annex 15: Farmer Participatory Research in the UK: A Guide.

KNOWLEDGE TRANSFER.

2002/03.

- Poster presentation at The RASE Royal Agricultural Show (29th June – 2nd July 2003), this highlighted the links with other DEFRA funded research at Elm Farm Research Centre, particularly project AR0914 – 'Generating and evaluating a novel genetic resource in wheat in diverse environments'. In addition, the IOR-HDRA participatory project OF0315 'Participatory investigation of the management of weeds in organic production systems' was presented on the same platform. The project formed part of a poster display at the Soil Association conference, 3-5th January 2003.
- The preliminary data and methods of the project have been presented at a number of farmer group meetings and meetings of organic seed producers. Articles about the project have been published in the Elm Farm Research Centre bulletin.

2003/04.

- Presentations were made at a NIAB members' day on 26th June 2004 and at a range of Arable farmer events during summer 2004.
- Talks on the project outcomes in relation to seed-borne diseases were presented at Organic Crops Demonstration Project (Abacus Organics). 2004
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- Farmer Event: 21st June 2005. Sheepdrove Organic Farm, Berkshire.
- Farmer Event: 28th June 2005. Wakelyns Agroforestry, Suffolk.
- Talks on the project outcomes in relation to seed-borne diseases were presented at Organic Crops Demonstration Project (Abacus Organics). 2005
- The NIAB element of work on seed-borne diseases was presented as a poster entitled "Occurrence of seed-borne diseases in UK Organic Cereal Seed and Approaches for their control" at the 5th International Seed testing Association Seed Health Symposium at Angers, May 2005.
- Presentation to COR meeting on participatory research in organic farming, Jan 25, 2005.
- Training day on participatory research approaches, March 18th and 25th, 2005.
    - Harris, F. 2005. Using Qualitative Methods in Farmer-Participatory Research Presentation to Colloquium of Organic Researchers (COR) meeting on Participatory research in organic farming. HDRA, Jan 25, 2005.
    - Harris, F. 2005. Using Qualitative Methods in Farmer-Participatory Research Training day on participatory research approaches. HDRA, March 2005.
- Presentations were made at NIAB, Cambridge, members' day in June 2005.

2005/06.

- Farmer Event: 27th June 2006. Sheepdrove Organic Farm, Berkshire.
- Farmer Event: 21st June 2006. Wakelyns Agroforestry, Suffolk.
- Talks on the project outcomes in relation to seed-borne diseases were presented at Organic Crops Demonstration Project (Abacus Organics). 2006
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9. This section should be used to record links (hypertext links where possible) or references to other published material generated by, or relating to this project.

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