PROJECT REPORT NO. 304

PRODUCTION OF ORGANIC WHEAT: TRIALS ON VARIETIES, SEED RATE, WEED CONTROL AND THE USE OF PERMITTED PRODUCTS

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PRODUCTION OF ORGANIC WHEAT: TRIALS ON VARIETIES, SEED RATE, WEED CONTROL AND THE USE OF PERMITTED PRODUCTS

by

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This is the final report of a 40-month project which started in September 1999 with a grant of £36,173 from HGCA (Project No. 2237).

Contents

Abstract

The organic wheat production area is continuing to expand but it is still far from supplying the needs of the end users in the UK. Current estimates of 50% of organic breadmaking wheat and 80% of feed wheat for animal feed being imported indicate the potential for continued expansion of the UK production of organic wheat grain.

Variety selection could be considered an even more important decision in the organic sector compared to the conventional sector and the three seasons of variety trials described in this project emphasise the need for great care when selecting wheat varieties for organic production. Traditionally organic growers would take much of their guidance from variety performance in conventionally grown trials but this project questions the wisdom of that strategy. Varieties such as Hereward and Exsept perform well in organic situations but some of the more traditional high yielding varieties like Savannah and Consort have done less well. It appears that to fully evaluate the performance of a variety for its suitability for organic production it should be tested in an organic situation,. Extrapolation from conventional trials may be useful but will not precisely define the most suitable varieties for organic production situations.

It would also appear that organic growers may not be able to follow the current trend in the conventional wheat production sector to reduce seed rates. Lowering seedrates was consistently associated with lower yields in this three season trials series.

In the quest for higher grain protein content growers in the organic sector have explored the value of products that contain seaweed extracts applied to crops. In the three seasons when seaweed extract products (and concentrated manure products) were applied to organic wheat crops no significant increases in yield were recorded. Some increases in grain protein content did result from treatment, up to 1.03% in one trial, but the economic value of this is uncertain unless the growers has a contract that is adjusted financially for protein content.

A more interesting potential input is sulphur. In view of the decreasing availability of sulphur to all crops as a result of lower sulphur deposition levels from the atmosphere, it was extremely interesting to find in the 2001 trials a significant increase in grain yield, up to 10%, as a result of a foliar application of sulphur. Sulphur deficiency is increasing in incidence in conventional crops and this trend may also be developing in organic wheat crops.

It is important that the value of sulphur to organic breadmaking wheat crops is more extensively evaluated and that techniques to select varieties for organic production are conducted in organic situations.

Summary

Whilst the organic wheat production area is expanding rapidly in the UK, the production area in 2002 being 8,300ha, the organic baking and animal feed industries are still importing very high proportions of their annual organic grain requirements.

Organic wheat production and organic grain quality are issues that are therefore facing the UK industry and both were addressed in this three year project which spanned the harvests of 2000, 2001 and 2002.

The main projects took place on an organic farm in Gloucestershire but in the third season some trials were also located on organic land in East Lincolnshire.

The topic areas that were addressed in this project were

- variety evaluation
- seed rates
- weed control
- approved and permitted products such as seaweed extracts and sulphur

Comparisons between wheat varieties were undertaken in all three seasons, the total variety numbers being 14, 25 and 10 in each of the three years. The mean yields of all varieties tested in each particular year were 3.62, 4.83 and 4.22 t/ha. The yield results did indicate that varieties performed differently, relative to other varieties, in organic situations. One good example of the differential performance was to be seen by noting the performance of Hereward. In conventional wheat growing this variety would routinely be one of the lowest yielding varieties in trial but for two seasons in organic trials it outyielded Malacca by 38% and 3.5%.

Deben, a feed wheat performed well in all three seasons but again it is interesting to note the performance of Exsept, a variety with excellent resistance to Septoria tritici. It would normally not be considered as a high yielding wheat under conventional growing but was the highest yielding variety in trial in the 2000 organic variety trial and second highest yielding in 2001.

It is important that organic growers are provided with information that reflects the farming circumstances under which they are growing varieties i.e. organic. If this is not the case then they may be given misleading information which could direct them towards the wrong variety choice.

It should also be noted that during the course of this project discussions with end-users suggested that they would prefer to receive grain from only a narrow range of varieties. This makes the task of meeting specifications laid down by processors easier if the starting point, the initial grain samples, are less varied.

Seed rates in the organic sector have traditionally been higher than those in the conventional sector and this trend was supported by the results from the project. Whilst yields did tend to plateau at higher seed rates (over 500 seeds/m^2) there was clear evidence that lower seed rates, less than 400 seeds/m^2, could be associated with lower yields. This evidence suggests that organic wheat growers may not be able to take advantage of the seed saving opportunities currently being used by conventional wheat growers when they reduce their seed rates.

Weed control operations in organic cereal crops are usually conducted during the winter and early spring months when weather conditions allow movement of vehicles and implements on the land. The location used for these trial produced rather low weed populations and this series of trials did not produce any significant increases in yield as a result of any of the weed control treatments.

Organic growers do have access to a range of products that can be used on organic cereal crops. These trials concentrated upon permitted products and they were directed at two areas

- protein enhancement of cereal grains
- the importance of sulphur

Increasing the protein content of organic grain destined for the breadmaking market is a very important objective of all organic growers. Many growers have begun to use seaweed extract products or concentrated manure formulations to try and boost protein contents and over three seasons five products of these types were evaluated. On no occasion over the three years of trials did any of the seaweed extracts or concentrated manure treatments produce significant increases in grain yield. The protein contents of the grains were improved by some treatments, the maximum increase being 1.03% in 2001 and 0.29% in 2002. Clearly these increases in grain protein will only be of economic importance to the grower if he is able to increase his financial return from the grain to an extent that covers the cost of the treatments.

The rapid decline in sulphur availability in the UK, that has resulted from the success of techniques to reduce atmospheric pollution, is creating a significant increase in the number of conventionally grown arable crops that are being reported as sulphur deficient. Sulphur deposition levels are now only 15% of those that were monitored 20 years ago and whilst the organic producer has the potential advantages of less S removal by crops (from lower yields) and more use of organic manures (which boost S levels in soils) there may be a sulphur deficiency problem developing in the organic cereal sector.

Sulphur applications were made on both Maris Widgeon and Malacca.

The trials in 2000 and 2002 did not produce significant yield responses to the applications of sulphur to crops of organic winter wheat. However in both those seasons a soil S test conducted on the trial area

revealed a level above the threshold level for S deficiency inferring that the crop would be unlikely to respond to sulphur applications.

In the 2001 season the soil S level was 9ppm compared to a deficiency threshold value of 10ppm, so it was marginally deficient. Two of the six sulphur treatments produced significant increases in grain yield, increases of 8% and 10%. These are the only results that ARC have produced in three years of trials where a significant yield increase resulted from a permitted product input.

These results may indicate that whilst the organic sector may be buffered to some extent from the problems of sulphur deficiencies it nevertheless must acknowledge the potential of a longer term threat from this deficiency.

This three year trial programme has produced valuable information on variety choice, seed rate manipulation and the potential longer term problem of sulphur deficiency in the organic cereal sector. It is important that the studies, particularly on variety choice and sulphur continue as these are ongoing decisions within the organic sector which could profoundly influence the profitability of crops.

Introduction

When this project commenced in September 1999 the organic wheat area in the UK was estimated to be almost 4,500 hectares but projected to expand rapidly. By harvest 2002, the organic area for wheat had reached 8,300 hectares. It was expected to reach 15,000 hectares by 2004.

However as over 50% of organic feed wheat and over 80% of organic wheat for flour production is still imported into the UK it is clear that the industry has a production and possibly a quality problem to overcome.

Organic cereal growers face identical decisions to those faced by conventional growers over factors such as variety choice and the production of grain that will satisfy the requirements of the end user. This three year project addressed those decisions by posing a series of agronomic questions :

- what is the most suitable wheat variety to select for organic production?
- how important is seed rate in organic crops?
- what is the effect of weed control on the yield of organic wheat?
- is the use of permitted products of value in organic wheat production systems?

The trials were conducted for three seasons at a location in Gloucestershire and supplemented in the final year of trialing (2002) by a small number of trials from a location in North Lincolnshire.

Trial Details

The primary location was on the Duchy Home Farm at Tetbury in Gloucestershire. This Cotswold brash soil type (Elmton 1 - brash clayey soil over limestone) is farmed on a seven-year rotation where the winter crop is the first of four arable crops after a three-year grass clover crop.

All trial plots were drilled as $20m^2$ plots and each treatment was replicated three times.

Variety Trials

These were drilled using seed direct from seed companies specialising in organic seed or from the plant breeding companies.

Quality analyses of grain from these trials and the other trials reported were undertaken by independent laboratories.

Weed Control

Weed control measures were implemented either by hand or through the use of a specially constructed harrow comb for ARC produced by Opico.

Permitted Products

The products both for grain enhancement and sulphur trials were applied using AZO precision plot hand held sprayers.

In autumn 2001 difficulties were experienced in establishing the trials in Gloucestershire and the original variety trial was discontinued due to inconsistencies in plant emergence. A second organic variety trial at the ARC location at Great Carlton in Lincolnshire was used to replace the original trial. This was located on a heavier soil than the Cotswold location described as 711u Holderness - fine loamy soil with slight waterlogging.

Variety Trials

2000

The trials in 1999/2000 were located at Tetbury in Gloucestershire and evaluated 14 winter wheat varieties and two variety blends.

The average yield from the trials was 3.62 t/ha (1.47 t/acre) having been drilled on 15th October 1999.

Variety Trial (2000 Harvest)					
Variety	**Yield (t/ha)**	**% of Site Mean**	**Specific Weight (kg/hl)**	**% Protein**	**HFN**
Exsept	5.17	143	70.9	-	-
Deben	4.33	120	67.0	-	-
Hereward	4.32	120	73.8	11.6	289
Claire	4.18	116	70.7	10.0	287
Maris Widgeon	4.00	111	74.7	13.0	222
Eclipse	3.79	105	64.3	11.4	312
Maris Huntsman	3.78	105	69.9	-	-
Maris Widgeon/Malacca (50/50 blend)	3.78	105	71.1	13.1	269
Maris Widgeon/Spark (50/50 blend)	3.52	97	72.3	12.3	274
Mercia	3.37	93	71.3	11.6	325
Avalon	3.31	92	69.6	12.8	274
Spark	3.24	90	69.5	10.4	338
Malacca	3.12	86	67.8	12.0	353
Consort	2.79	77	64.1	-	-
Riband	2.73	76	64.8	-	-
Savannah	2.41	67	65.0	-	-
Site Mean yield = 100%	3.62 (t/ha)				
LSD 0.44 t/ha CV 7.31%					

The two quality wheats favoured by organic growers, Hereward and Maris Widgeon performed well but another quality wheat Malacca was lower yielding. Exsept, a wheat with excellent *Septoria tritici* resistance, was clearly the highest yielding but Deben also performed well.

Deben and Hereward produced similar yields in this organic trial but in ARC conventionally farmed trials only 15 miles away on a similar soil type Deben outyielded Hereward by 20%.
The feed wheat Savannah and biscuit wheats, Consort and Riband, all of which were very popular on conventional farms at that time, performed badly.

The concept of variety mixes has been advocated in many crops on many occasions and its advantages are claimed to lie in the fact that different varieties have leaf structures that will occupy different parts of the crop canopies. Critics of mixtures suggest that end-users do not require mixed varieties and if they do so they would prefer to blend them under controlled conditions in a processing plant rather than in the field.

These two mixtures both yielded less than the highest yielding component (Maris Widgeon) and in the case of the Maris Widgeon/Spark blend the yield reduction was significant.

2001

The trials were expanded in 2000/01 and 25 varieties were evaluated at the same location as the previous year.

Variety	Yield (t/ha)	% of Site Mean	Specific Weight (kg/hl)
Deben	5.54	115	71.3
Macro	5.31	110	69.0
Exsept	5.31	110	75.3
Claire	5.17	107	72.9
Option	5.16	107	69.7
Phlebas	5.12	106	70.1
Tanker	5.10	106	66.6
Biscay	5.06	105	69.5
Hereward	5.00	104	71.3
Oxbow	4.95	102	73.4
Napier	4.94	102	65.4
Marshal	4.92	102	69.6
Milestone	4.91	102	68.3
Access	4.91	102	69.0
Malacca	4.83	100	68.6
Richmond	4.76	99	73.4
Storm	4.76	99	70.5
Xi19	4.70	97	71.6
Chatsworth	4.64	96	71.9
Mercia	4.64	96	73.0
Solstice	4.63	96	71.9
Petrus	4.50	93	79.1
Spark	4.18	87	70.4
Maris Widgeon	3.96	82	73.0
Avalon	3.85	80	68.1
Site Mean Yield	4.83 (t/ha)		
LSD	0.48 (t/ha)		
CV	6.43%		

Deben and Exsept both again performed well in 2001 with Macro also doing well. Claire, fourth highest yielding variety in 2000 was fourth again in 2001.

Hereward again produced an excellent yield outperforming Maris Widgeon by 26% compared to 8% in 2000.

The site mean yield of 4.83t/ha was 1.21t (+33%) higher in 2001 compared to 2000, the drilling date being 19th October 2000.

2002

The 2001/02 trials were conducted in North Lincolnshire at Great Carlton as a result of the problems encountered at the Gloucestershire location. As this was not initially designated as the primary organic variety trial location the number of varieties in trial was considerably reduced compared to previous years, only 10 being evaluated. The trials were drilled on 1st November 2001.

Variety Trial (2002 Harvest)					
Variety	**Yield (t/ha)**	**% of Site Mean**	**Specific Weight (kg/hl)**	**% Protein**	**HFN**
Biscay	4.79	113	73.5	-	-
Claire	4.64	110	72.4	-	-
Deben	4.42	105	71.8	-	-
Macro	4.19	99	68.3	-	-
Exsept	4.15	98	74.0	-	-
Option	4.15	98	73.6	9.31	212
Aadvark	4.08	97	69.8	-	-
Malacca	4.00	95	72.0	9.26	202
Hereward	4.00	95	73.5	10.06	99
Milestone	3.81	90	76.9	-	-
Site Mean Yield	4.22 (t/ha)				
LSD	0.40 (t/ha)				
CV	5.53%				

Biscay, a hard feed wheat, was the highest yielding variety at this location but again Deben and Claire performed well. Hereward produced a yield equal to that of Malacca whereas in the two previous years it had outyielded Malacca by 38% (2000) and 3.5% (2001)

The three seasons of data clearly indicate the superiority of certain individual varieties in organic situations. They also suggest that the performance of varieties under conventional farming practices may not assist in the selection of varieties for organic crops as varieties performing well under organic conditions are not necessarily the varieties that are the highest yielding in conventional systems.

An examination of the suitability of non-organic variety trials for selecting correct 'organic' varieties can be undertaken using the data presented earlier in comparison to ARC conventional variety trials.

In all three seasons ARC conducted trials using conventional agronomic inputs of fertiliser and pesticides relatively close to those fields conducting organic trials. The comparisons are not statistically valid but that is not possible to achieve with the nature of the two trial types.

The comparisons are restricted to fewer varieties but they do illustrate the variation in relative performance that exists between 'conventional' and organic variety trials.

Performance comparison of conventional and organic (t/ha) (Gloucestershire 2000)	
Conventional	**Organic**
Claire 10.29	Exsept 5.17
Deben 9.79	Deben 4.33
Savannah 9.22	Hereward 4.32
Consort 9.02	Claire 4.18
Exsept 8.98	Malacca 3.12
Malacca 8.46	Consort 2.79
Hereward 8.18	Savannah 2.41

The relative order of performance, apart from Deben, changes dramatically under the two production systems.

In 2001 Deben topped both lists but again the performances lower down the yield tables did vary according to the production system.

Performance comparison of conventional and organic (t/ha) (Gloucestershire 2001)	
Conventional	**Organic**
Deben 9.87	Deben 5.54
Claire 9.33	Macro 5.31
Xi 19 8.86	Exsept 5.31
Exsept 7.88	Claire 5.17
Hereward 7.78	Biscay 5.06
Macro 7.68	Hereward 5.00
Malacca 7.25	Malacca 4.83
Biscay 7.23	Xi19 4.70

The yield range in the organic trials was considerably narrower than in the conventional trial

Performance comparison of conventional and organic (t/ha) (Lincolnshire 2002)	
Conventional	**Organic**
Biscay 10.15	Biscay 4.79
Claire 9.94	Claire 4.64
Option 9.90	Deben 4.42
Deben 9.60	Macro 4.19
Macro 9.43	Option 4.15
Malacca 8.75	Malacca 4.00

There was closer agreement in 2002 with only Option changing its relative position. Nevertheless the overall trend is for the conventional variety performance to not fully reflect the probable performance of a variety in an organic production regime. It would appear that to enable the organic sector to be provided with information to allow correct variety selection, the information should be generated in an organic

situation. Without that support the organic grower may select varieties that are not best suited to the circumstances in which they will be grown.

Another feature is the suitability of varieties for the end users.

It appears that the milling and baking industry prefer organic growers to present them with a narrower range of variety options than are presently presented. Consistency of flour quality can be more easily and best maintained by millers working with fewer varieties of wheat. Whilst it is tempting to evaluate all varieties in organic situations, mirroring the conventional sector, in reality the end user requirements should be more widely adopted and variety choice should be more focussed in the organic sector.

The Influence of Seed Rate

It has traditionally been considered that seed rates in organic winter wheat crops should be higher than those routinely used in conventionally grown wheat crops for two main reasons.

- higher seed rates should result in higher plant populations which will give better weed suppression.
- higher plant populations will give greater numbers of primary tillers which should be heavier yielding than secondary tillers.

An HGCA-funded Research Review (No 45) "Current practices and future prospects for organic cereal production : survey and literature review" has published very useful information on seed rates in the organic cereal sector and on other agronomic aspects of organic cereal production.

Part of the Review contained survey data obtained from organic growers.

The seed rates used by the respondents to the survey were clearly higher than those used in conventionally grown crops.

Comparison of seed rates used in organic winter wheat crops with those used in conventional	
Below Average	0%
Average	25%
Above Average	75%
Source: HGCA	

All recipients used the same or more seed in organic crops than conventional crops. It was also interesting to note the response of growers as to the effect of this higher seed rate practice upon yield.

Influence of seed rate on yield of organic winter wheat	
Seed Rate	**Yield (t/ha)**
Below Average	2.8
Average	4.4
Above Average	4.3
Source: HGCA	

Growers clearly recognised the advantages of higher seed rates as higher yields but the survey did not explore the actual seed rates used.

In these trials there were a range of seed rates from 200 to 500 seeds/m^2. Clearly in different seasons these would result in different plant populations and this variable is noted in the results reporting.

Harvest 2000

Influence of Seed Rate on yield and grain characteristics (Maris Widgeon)					
Seed Rate (seeds/m^2)	**Plants/m^2**	**Yield (t/ha)**	**% of Control**	**Specific Weight (kg/hl)**	**TGW (gms)**
200	85	2.67	95.4	71.1	48.4
300	118	2.62	93.6	72.8	49.2
400 (c)	172	2.80	100	72.6	45.2
500	220	2.96	105.7	72.9	49.2
CV 9.4% LSD 0.47 t/ha					

At the two highest seed rates yields were higher (but not significantly) than at the two lower seed rates.

Specific weights tended to increase as the seed rate increased.

Seed Rate (seeds/m^2)	Plants/m^2	Yield (t/ha)	% of Control	Specific Weight (kg/hl)	TGW (gms)
200	116	3.07	85.3	71.4	45.6
300	92	3.26	90.6	74.0	47.6
400 (c)	143	3.60	100	74.2	47.8
500	187	3.95	109.7	73.3	47.0

The 300 and 200 seeds/m^2 were significantly lower yielding than the 500 seeds/m^2 which was the highest yielding seed rate. The 200 seeds/m^2 was also significantly lower yielding than the 400 seeds/m^2.

Harvest 2001

In both varieties, Hereward and Maris Widgeon, the established plant populations increased as seed rates increased, producing populations of 113 to 246 plants/m^2 in Hereward and 110 to 268 plants/m^2 in Maris Widgeon.

The influence of seed rate on yield and grain characteristics (Hereward)						
	Plants /m^2	**% Establishment**	**Yield (t/ha)**	**% of Control**	**Specific Weight (kg/hl)**	**TGW (g)**
Seed Rate/m^2						
200	113	57	4.51	103.0	75.1	52.8
300	161	54	4.70	107.3	75.3	54.6
400 (c)	181	45	4.38	100	75.6	52.8
500	246	49	4.51	96.0	76.1	52.0
LSD 0.24 t/ha CV 2.7%						

Yields peaked at 300seeds/m^2, this seedrate significantly outyielding 400/m^2.

There was a very slight increase in specific weight as the seed rate increased but the highest TGW was produced by the highest yielding treatment 300 seeds/m^2 (161 plants m/^{2}).

The identical seed rate also produced the highest yield in Maris Widgeon (along with 500 seeds/m^2) and it was also recorded in having 161 plants/m^2.

The influence of seed rate on yield and grain characteristics (Maris Widgeon)						
	Plants /m^2	**% Establishment**	**Yield (t/ha)**	**% of Control**	**Specific Weight (kg/hl)**	**TGW (g)**
Seed Rate/m^2						
200	110	55	3.74	96.4	76.4	57.2
300	161	54	3.95	101.8	76.3	55.8
400 (c)	208	52	3.88	100	76.3	55.8
500	268	54	3.96	102.1	76.7	56.0
LSD 0.18 t/ha CV 2.2%						

Both the 300 and 500 seeds/m^2 significantly outyielded the 200 seeds/m^2.

The 2001 harvest results suggested that seed rates above 300 seeds/m^2 may not increase yield but below that level there was a possibility of yield reduction.

Harvest 2002

This trial was conducted at the ARC (Great Carlton) location in Lincolnshire as opposed to the two previous seasons where the trials were conducted at ARC (Tetbury) in Gloucestershire.

The two varieties used in these trials were Claire and Malacca.

The influence of seed rate on yield and grain characteristics (Claire)					
	Plants /m²	**% Establishment**	**Yield (t/ha)**	**% of Control**	**Specific Weight (kg/hl)**
Seed Rate/m²					
300	144	48	4.38	99.1	72.8
400 (c)	188	47	4.42	100	72.3
500	210	42	4.39	99.3	73.1
600	216	36	4.68	105.9	72.5
LSD 0.28t/ha CV 3.08%					

The seed rates used at this location were higher than those used in Gloucestershire as the soil was heavier and past experience indicated higher rates would be required.

No seed rate produced a yield that was significantly different from that of the control treatment (400 seeds/m^2). However the 600 seeds/^{2} significantly outyielded the 300 seeds/m^2, the plant populations being 216 and 144 plants/m^2 respectively.

The influence of seed rate on yield and grain characteristics (Malacca)					
	Plants /m²	**% Establishment**	**Yield (t/ha)**	**% of Control**	**Specific Weight (kg/hl)**
Seed Rate/m²					
300	153	51	3.47	89.4	73.3
400 (c)	204	51	3.88	100	71.9
500	240	48	3.70	95.4	72.9
600	252	42	3.94	101.5	72.8
LSD 1.05 t/ha CV 12.32 %					

The % levels of establishment again showed a decline as seed rates increased but there was still a wide range of plant populations from 153 to 252 plants/m^2.

The high CV confirmed the fact that the inherent fertility in the field varied considerably and interpretation of these results is therefore difficult.

Over the three seasons of trials it is possible to produce a summary of yield performance monitored against seed rate but the high CV Malacca trial in 2002 has been omitted from the analysis.

The influence of seed rate on yield and grain characteristics			
Seed Rate/m^2	**Range of Plants/m^2**	**Yield (% of Control)**	**Range**
200	85-116	95.0	85.3 to 103.0
300	92-161	98.5	90.6 to 107.3
400 (c)	143-208	100	100
500	187-268	102.6	96.0 to 109.7
600*	216	105.9	
* only 1 trial included			

This would suggest that seed rates below 400 seeds/m^2 may not be ideal for organic wheat situations. The gradual lowering of seed rates in the conventional sector may not be a pattern that can be followed by organic cereal growers.

Weed Control

Weeds were considered by 51% of the growers surveyed in the HGCA study as being the main problem associated with organic cereal production.

One of the most effective approaches for weed control, particularly of broad leaved weeds is to use some form of comb harrowing. There are times in the season when the crop is able to overcome weeds or tolerate weeds but at other times the crop may be vulnerable to weed competition and this is termed the 'critical weed free period'. This is generally accepted to be, in autumn sown cereals, from November until the end of March.

Weed control technically can be a season-long operation often beginning with rogueing in the preceding crop. The use of stale seedbeds plus harrow combing, before the crop is drilled, will again significantly reduce weed populations.

Any combing operation will remove some crop plants thereby raising the prospect of slight yield reduction if the weeding action was not necessary. This is often offset by the use of slightly higher seed rates to compensate for crop plant losses.

Harrow combing should ideally be conducted when the soil is reasonably dry and the weather is dry. This will ensure that any weed seedlings that are disturbed will desiccate more rapidly.

Weed Control and Seed Rate

In the 1999/2000 season ARC trials explored the interaction between seed rate and weed control. The trial location had relatively low broad-leaved weed populations and the site was originally selected as having a low grass weed problem.

The trials used two seed rates and incorporated both harrow combing and hand weeding (possible in replicated trial plots).

Responses to Seed rate and weed control (2000 - Maris Widgeon)				
Seed Rate/m^2	**Weed Control**	**Yield (t/ha)**	**% of Control**	**Specific Weight (kg/hl)**
200	None	2.67	95.4	71.1
200	Harrow Comb	2.85	101.8	73.6
400 (c)	None (c)	2.80	100	72.6
400	Harrow Comb	3.08	110.0	74.0
400	Hand Weed	2.85	101.8	73.3
400	Harrow Comb + Hand Weed	2.93	104.6	74.3
CV 9.4% LSD 0.47 t/ha				

(harrow comb - 1 pass on March 31st. Hand weeding on same day)

There were no significant differences between any of the treatments but some interesting trends were apparent. The higher seed rate outyielded the lower seed rate in all treatments. Also every time a method of weed control was employed the yield increased.

Specific weights increased when weed control measures were applied.

Responses to Seed rate and weed control (2000 - Hereward)				
Seed Rate/m^2	**Weed Control**	**Yield (t/ha)**	**% of Control**	**Specific Weight (kg/hl)**
200	None	3.07	85.3	71.4
200	Harrow Comb	3.06	85.0	71.4
400 (c)	None (c)	3.60	100	74.2
400	Harrow Comb	3.60	100.8	73.1
400	Hand Weed	3.70	102.8	72.4
400	Harrow Comb + Hand Weed	3.61	100.3	71.6
CV 6.3% LSD 0.39 t/ha				

(harrow comb - 1 pass on March 31st. Hand weeding on same day)

The weed control measures at 200 seeds/m^2 had no effect on yield or specific weight and both treatments were significantly lower yielding than all treatments drilled at 400 seeds/m^2.

No significant yield responses or improvements in specific weights were produced from the weed control treatments applied to the 400 seeds/m^2 plots.

The results in this low weed pressure location, did not demonstrate any significant response to weed control measures.

The research literature suggests responses to weed control can be as high as 50% yield improvement and often be in the range of 20-25% yield improvement. These values were not generated in these two trials.

The use of permitted products

The Soil Association standards cover all aspects of farm management to ensure a sound and sustainable organic farming system.

Materials are classified as Recommended, Permitted, Restricted or Prohibited. The two categories that effect this report are Permitted and Restricted.

Permitted

These are products which can be used under the Soil Association Standards.

In the grain quality enhancement trials reported here the following products were classed as permitted : Seasol, Maxicrop, SM6, Marinure, Super Natural Liquid Plant Food (SNLPF)

Restricted

Permission must be granted from the Certification body before these products can be applied. A soil or leaf analysis will be required for restricted products. Sulphur applied as a fertiliser is a restricted product under Soil Association Standards.

It is possible to apply sulphur in a fungicidal form and in the sulphur trials two products, Solfa and micro - S were applied as foliar fungicide applications to enable sulphur applications to be made to the crop under permitted product status.

Grain Quality Enhancement

Providing organic crops with sufficient nutrients is one of the primary and most difficult objectives facing the organic grower.

The HGCA survey confirmed the role of correct crop rotation in the planning practices of the majority of organic growers.

Methods of N fertility in organic cereal crops	
	(% of cereal crops)
Rotation	90%
Home-produced manure	48%
Green Manures	12%
Bought-in manures	9%
Other *	5%

* mainly outdoor pigs Source : HGCA

In the wheat crop however the second problem, apart from providing enough nutrients in the soil to promote yield, is to increase the grain protein content of breadmaking wheat to make it attractive to the millers.

Boosting grain protein contents is widely practised in the conventional sector by the use of solid N or liquid N applications at any time between GS37 and GS69. The organic growers options are more limited and the HGCA survey revealed the common practices employed by organic growers, to supplement 'rotational' fertility.

Bought in nutrients (excluding lime, P and K)	
	(% crops)
Organic manure	23%
Other *	20%
Organic fertiliser	3%
Organic waste	1%

* mainly seaweed products Source : HGCA

Fertility supplements that are most commonly directed towards enhancing grain protein levels are seaweed based products.

The trials evaluated four products based upon extractions from seaweed plus a concentrated cow manure product (SNLPF). They were applied according to recommendations by the product suppliers which involved either two or three applications during the growing season.

The influence of permitted products on yield and grain quality

Maris Widgeon - 2000					
	Application	**GS**	**Yield (t/ha)**	**% of untreated**	**Specific Weight (kg/hl)**
Untreated			2.43	100	62.5
Seasol	200g/ha	30 + 39	2.80	115.1	63.4
Maxicrop	1l/ha	30 + 59	2.45	100.8	66.1
SM 6	1.4l/ha	31 + 39	2.62	107.6	64.7
Marinure	3 or 4l/ha	30 + 32 + 59	2.48	101.8	64.9
SNLPF	4l/ha	30 + 32 + 59	2.74	112.4	66.4
CV 21.9% LSD 1.01t/ha					

Once again the problem of inconsistency of fertility across organic fields affected these results and produced an unacceptably high CV. The main response from the applications were yield increases but none were significant due to the variability of the trial.

No samples were assessed for quality in this trial due to the inconsistency of yield responses.

In 2001 the treatments were repeated, this time on the variety Malacca.

The influence of permitted products on yield and grain characteristics Malacca - 2001						
Product	**Timing (s)**	**Yield (t/ha)**	**% of untreated**	**Specific Weight (kg/hl)**	**% Protein**	**HFN**
Untreated	-	5.08	100	70.4	9.68	251
Seasol 200g	GS31 + 59	4.97	98	71.5	10.11	259
Maxicrop 1l/ha	GS31 + 39	5.05	99	71.5	9.86	327
SM6 1.4l/ha	GS31 + 39	5.19	102	72.5	10.29	348
Marinure	3l/ha GS31 4l/ha 33 & 59	4.87	96	70.7	10.23	289
SNLPF 4l/ha	GS31 + 33 + 59	5.20	102	71.0	10.71	279
CV 4.2% LSD 0.37t/ha						

None of the five treatments produced yields significantly different from that of the untreated crop. However in all cases the % protein of the grain increased as a result of product application but from the low base point of only 9.7%. The greatest improvement was a protein increase of + 1.03% from the three applications of SNLPF.

The trials in 2002 again used Maris Widgeon (as in 2000).

The influence of permitted products on yield and grain characteristics Maris Widgeon - 2002					
	Yield (t/ha)	**% of control**	**Specific Weight (kg/hl**	**% Protein**	**HFN**
Untreated	6.29	100	78.1	11.73	252
Seasol 200g/ha 49-59	6.57	104.5	78.0	11.98	231
Maxicrop Original 1l/ha 49-59	6.50	103.3	78.0	12.02	248
SM6 1.4l/ha 20-25 SM6 1.4l/ha 49-59	6.51	103.5	77.9	11.83	229
Marinure 4l/ha 20-25 Marinure 3l/ha 49-59	6.55	104.2	79.0	11.78	173
Super Natural LPF 4l/ha 49-59	6.17	98.2	78.4	11.85	248
CV 5.35% LSD 0.60t/ha					

Once again no treatment produced a yield which was significantly different from that of the untreated control. The protein contents were all increased by the product application, from 0.05% to 0.29%.

The trials over three seasons did not produce any evidence of a significant yield response from the application of the five products.

Grain % protein contents were improved by a maximum of 1.03% (SNLPF) in 2001 and 0.29% (Maxicrop) in 2002. The value of these small improvements in financial terms is very dependent upon the individual contracts agreed between each grower and end user.

The Value of Sulphur

Sulphur is a vital secondary element for all crops being an essential component of amino acids such as cysteine and methionine and involved in numerous enzyme reactions in plants.

Historically sulphur deficiency in crop plants has never been a problem in the UK as it has been available through atmospheric pollution and delivered to crops through rainfall. However, the success of campaigns to reduce environmental pollution, have now reduced sulphur deposition levels to only 15% of those which existed twenty years ago. Whilst this is an environmental success story it is creating an increasing number of problems in the agricultural sector. Sulphur deficiency in agricultural crops is increasing in frequency dramatically and in the non-organic sector some of the yield improvements from the application of relatively small amounts of sulphur (20 - 40kg/ha S depending upon crop) have been spectacular.

Yield improvements following sulphur applications
(ARC trials 2001)

Winter Oilseed Rape	+ 48%
Winter Wheat	+ 34%
Winter Barley	+ 25%
Spring Barley	+ 31%

These figures have obviously been generated in crops known to be sulphur deficient but the incidence of those crops is increasing. Recent estimates based upon factors such as rainfall, soil type and deposition levels suggest that 50% of the UK rape area is now at risk of S deficiency and 30% of the cereal area.

It is very probable therefore that in the non-organic sector yield improvements from sulphur applications will be found more frequently and many growers particularly on lighter soils, or in areas of lower rainfall or where there is little or no access to organic manures will be considering S applications as a routine input.

In the organic sector many cereal producers do use rotations that involve livestock so one of the main methods of replenishing S, the addition of organic manures, is regularly used. However against this backdrop of S levels declining nationally, will the organic cereal producer face problems in the future and are they already evident?

For three seasons trials were conducted in first wheats that were following three years of grass/livestock at the location in Gloucestershire.

2000

A soil sample indicated a sulphur level of 13ppm when analysed in mid October 1999. This is considered as Sulphur sufficient against a threshold value of 10ppm.

The crop of Maris Widgeon was treated with two sulphur-containing products, Solfa or Micro-Sulphur and with both products applications were made on two occasions during the season.

In addition both products had additional treatments which included the product Codacide Oil, an adjuvant.

Influence on grain yield and grain characteristics 2000 - Maris Widgeon				
Treatment	**Rate**	**Yield (t/ha)**	**% of control**	**Specific Weight (kg/ha)**
Untreated	-	2.43	100	62.5
Solfa	10kg GS 32 10kg GS39	2.68	110.1	69.3
Solfa - Codacide	10kg GS32 10kg GS 39 (10l/ha) x 2	3.36	137.9	70.2
Micro Sulphur	10kg/ha GS32 10kg/ha GS39	2.85	117.0	71.2
Micro Sulphur + Codacide	10kg/ha GS32 10kg/ha GS39 (10l/ha) x 2	2.97	121.9	70.4
CV 21.9% LSD 1.01t/ha				

These trial plots were located in a part of the field that produced extremely variable performances between the replicates. This resulted in a high CV value and a high LSD unlike the variety trial reported earlier that was in the same field. It was therefore not possible to identify significant yield responses but all sulphur applications did improve yield performance and specific weight.

Harvest 2001

In the autumn of 2000, prior to the application of any of the products a soil analysis revealed a sulphur level of 9ppm in the soil. Compared to a threshold level of 10ppm, this would be considered marginally deficient in sulphur.

Influence on grain yield and grain characteristics 2001 - Malacca						
Treatment	**Timing**	**Yield (t/ha)**	**% of control**	**Specific Weight (kg/hl)**	**% Protein**	**HFN**
Solfa 10 kg/ha	GS32 + 39	5.61*	110	73.1	10.7	295
Solfa + Codacide	GS32 + 39	5.18	102	73.1	9.9	337
Solfa + ½ Codacide	GS32 + 39	5.22	103	72.7	9.9	316
Micro-Sulphur 10kg	GS32 + 39	5.41	106	72.9	9.84	293
Micro S + Codacide	GS32 + 39	5.47*	108	73.0	10.6	290
Micro S	GS32 + 39 + 39	5.31	105	73.0	10.4	282
Untreated	-	5.08	100	70.4	9.68	251
LSD (yield) 0.37t/ha CV 4.2% * significantly different to untreated control						

Two treatments (Solfa and Micro-Sulphur with Codacide oil) gave statistically significant yield increases. However, for both Solfa and Micro-Sulphur, the addition of Codacile oil did not give a significant yield response compared to the products used alone, though it did appear to improve protein level when used with Micro-Sulphur. Making a third application of Micro-Sulphur, at GS59 also improved grain protein.

Since foliar disease was absent in this trial, it may be assumed that the responses to the sulphur compounds were due to a sulphur deficiency rather than to their foliar fungicidal properties.

Harvest 2002

These trials were conducted on the variety Maris Widgeon. A soil sample revealed a sulphur level in this first wheat crop of 15ppm so this soil was not classed as sulphur deficient by that prediction system.

Influence on grain yield and grain characteristics 2002 - Maris Widgeon						
Treatment	**Rate and Timing**	**Yield (t/ha)**	**% of control**	**Specific Weight (kg/hl)**	**% Protein**	**HFN**
Untreated	-	6.29	100	78.1	11.93	252
Solfa	10kg/ha 49-59	6.07	96.5	79.0	11.77	198
Solfa _ Codacide Oil	10kg/ha 39-59	6.49	103.2	78.5	11.69	240
Micro-Sulphur	10kg/ha 49-59	6.35	101.0	78.5	11.61	227

There were no significant differences between any of the treatments in this trial. On 3rd July a sulphate:malate test was conducted on the leaf tissue of the untreated crop to determine the sulphate:malate ratio to give an indication of the likelihood of a sulphur deficiency. The result was a ratio of 1.5 : 1 which is exactly on the borderline of the current level of thinking regarding deficiency.

The lack of response in 2002, compared to 2001, reflects exactly the majority of sulphur trials in the conventional sector. Field responses in the conventional sector in 2001 were high but virtually disappeared in 2002. This may be a result of the autumn/winter rainfall pattern in the two seasons but this will need further studies before any firm conclusions can be reached.

Nevertheless, these results have great potential significance to the organic cereal sector as they suggest that the problems of sulphur deficiency, which are increasing each year in the conventional arable sector, may also be as important in the organic arable sector.

Discussion

The three year trials programme has produced a number of very important conclusions which are relevant to both producers of organic winter wheat crops and end users of the crop who are requiring grain with specific characteristics.

The variety trials have illustrated that whilst some varieties appear to perform well under both organic and conventional production systems, it is not a feature that is common to all varieties. The process of selecting varieties for organic production of grain does involve consideration of all those factors that are normally considered during the conventional selection process. However usually more emphasis is placed upon the disease resistance characteristics of the variety and unlike the conventional sector some growers consider the growth habit of the plant. Many organic growers believe that vigorous early growth and taller varieties ensures more weed suppression in organic crops and that these are therefore desirable characteristics. These are less relevant in conventional variety testing. This is one of the reasons, apart from the excellent baking quality, why Maris Widgeon is still a popular wheat variety for organic growers.

The evidence from the variety trials over the three seasons suggests that variety selection based upon performance in conventional variety trials may not be the best way in which to decide the most suitable variety for an organic wheat slot in the rotation. Testing of cereal varieties destined to be grown organically should be conducted in an organic situation thereby reflecting the circumstances in which the varieties will be grown.

It is also clear from discussions with end users, particularly millers, that they would prefer access to larger quantities of fewer varieties. This enables the miller to produce more consistent flour characteristics from a less variable intake of material. Organic growers, as a result of the smaller market and more focused end uses, should be trying to narrow their variety options wherever possible. This actually places more emphasis on correct choice and the need for trials in which varieties are compared in situations reflecting the growers subsequent production techniques.

The seed rate studies supported the view already held in the industry that optimum seed rates in organic winter wheat are higher than those used in the conventional wheat production sector. There has been a considerable trend over the past few seasons for seed rates in the conventional sector to decline as growers realised the 'over insurance' in seed rates that had been historically adopted. The trend for earlier drilling has also encouraged lower seed rates.

It is unlikely that this trend towards lower seed rates will be adopted in the organic wheat sector.

Whilst the milling industry will accept organic wheat with much lower protein levels than those accepted in the conventional sector there is still the same need in both sectors to present to these end users the highest protein levels that are technically/economically possible. A technique that has been suggested to assist organic wheat producers in this objective, and possibly also improve yields, is to use formulated extracts of seaweed on a regular basis through the season.

This technique was evaluated over three seasons using four seaweed extract products and a formulation of concentrated cow manure. On no occasion did any of the five treatments produce a significant yield improvements in the three seasons of trials. However some improvements in % grain protein levels were recorded, the maximum responses being + 1.05% protein increase in 2001 from the concentrated cow manure and 0.29% increase in 2002 from an application of Maxicrop. It is for the grower and his end user to decide if these increases justify the input expenditure in relation of the contracts that exist for specific grain characteristics. There is no doubt that % protein increases did occur on a regular basis from the seaweed extract applications and the concentrated cow manure applications but they were relatively small.

It is well known that sulphur is also very firmly implicated in the suitability of a grain sample for breadmaking. Lack of sulphur can reduce the production of some of the desirable glutens in flour and produce inferior loaves. This is becoming an increasing problem in the non organic sector as the well-documented decline in atmospheric sulphur deposition is creating more widespread and frequent examples of sulphur deficiencies in arable crops.

The results from the sulphur applications in these trials, particularly the 2001 season would suggest that the organic sector also faces the longer-term threat of sulphur shortage. The increase in sulphur deficiency may be less dramatic in the organic sector as two factors, the use of organic manures and the generally lower offtakes from lower yielding crops, will result in lower levels of sulphur depletion in soils. However the fact that sulphur applications did produce significant yield responses has been brought to the attention of the Soil Association who have indicated that the potential problem will be discussed by their Standards Committee.

The three-year project has highlighted some important factors concerning variety choice, the adjustment of seed rates in organic wheat crops and the potential value of permitted inputs to crops. A number of technology transfer events (field days and Conferences) have ensured that the results have been communicated into many parts of the organic sector. A number of growers are reviewing in particular the sulphur status of their crops as a result of these interesting findings.

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