DEPARTMENT for ENVIRONMENT, FOOD and RURAL AFFAIRS

Research and Development

Final Project Report

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Project title	Testing the sustainability of stockless arable organic farming on a fertile soil
DEFRA project code	**OF0301**
Contractor organisation and location	ADAS Terrington Terrington St Clement King's Lynn PE33 4PW
Total DEFRA project costs	£ 179,534.00
Project start date	04/01/01
Project end date	31/03/02

Executive summary (maximum 2 sides A4)

This work contributes to DEFRA's policy objective of promoting a sustainable, competitive and safe food supply chain which meets consumers' requirements. It helps to identify sound methods of organic farming, limiting factors and ways of overcoming them. To expand in the arable east of England, where the knowledge, infrastructure and capital for livestock are not available, viable stockless systems will be necessary. Projects OF0145 showed that in the first crop sequence after conversion, a stockless arable rotation was consistently more profitable that a comparable conventional rotation on the fertile silty clay loam soil at ADAS Terrington. However, sustainability in terms of nutrient supply, perennial weed control, soil-borne pests, and other pests and diseases will be increasingly challenged in subsequent crop cycles. Also, as UK organic crop production increases, and imports become more available, difficult market conditions are challenging economic sustainability. Project OF0301 was a one-year extension to OF0145 study to maintain core monitoring pending the DEFRA review of Organic Farming Research in 2001. Following the review, a proposal was submitted to DEFRA for a longer-term development of the core activities of this project.

The project was a combination of an unreplicated system study, replicated experiments and monitoring of commercial farms. A steering group consisting of representatives of DEFRA, Soil Association, Elm Farm Research Centre and three farmer members guided the project.

The core of the project was an unreplicated system study with field-scale plots to allow meaningful study of patchy problems such as perennial weeds and give confidence to farmers that the system could work on a farm scale. Conversion to organic methods was started in 1990 and was completed in 1995; the land is currently certificated by the Soil Association. The rotation is clover, potatoes and calabrese, winter wheat, spring beans, undersown spring cereal. There are five plots, each of 2 ha, and each is a different phase of the five-year rotation. In a study of ten commercial organic farms ('Linked-farms'), costings were done to Net Farm Income level, and compared with results for similar conventional farms from Farm Business Survey data and with Terrington organic and conventional crops. Linked-farm results are for 2000, due to the unavoidable time delay in collecting and analysing data.

Rainfall at Terrington between September 2000 and April 2001 was particularly high with some months having double the long-term average. This led to very few days with the soil dry enough to travel on, or to work with machinery, increased leaching losses of nitrogen (not measured in this project) and delayed sowing into poor seedbeds. The summer of 2001 was also wet, particularly July. This led to ideal conditions for slugs and for potato blight. This was the most difficult year for organic production since the start of the project.

Disease levels in cereals were again very low and posed minimum threat to yields. However, slugs caused serious problems, eating virtually all calabrese plants after one particularly wet day in May when 30 mm of rain fell, writing off the crop. Potatoes could not be planted until early May and were then affected by both blight and slugs. This reduced saleable yield to only 18.8 t/ha. Marketing as organic produce proved impossible, mainly due to over-supply, and the crop was sold for only £16/t for conventional processing. Despite these problems, rolling average crop yields remain good at 24.3 t/ha for potatoes, 7.3 t/ha for winter wheat, 3.5 t/ha for spring beans and 4.1 t/ha for spring cereals. This represent a reduction, compared to conventional, of 20% for winter wheat and 43% for potatoes. Despite the poor potato crop in 2001, weighted rolling-average gross margins still showed an advantage to a modelled organic rotation including potatoes (£855/ha conventional rotation at Terrington vs. £1568/ha stockless organic with potatoes). However, the generally lower profitability of vegetables, and the write-off of the 2001 calabrese crop, resulted in an average weighted rolling-average gross margin of £859/ha from a modelled organic rotation including vegetables, similar to the performance of the conventional rotation.

Soil fertility as measured by carbon content has shown little change since the start of conversion in 1990. The lack of a marked increase is not unexpected, as returns of crop residues were not significantly greater than in the conventional cropping replaced. Soil available P and K have remained at ADAS Index 1 to 2 despite continued crop offtakes. However, both are showing a slow progressive decline. Further assessment will be necessary to determine how this will develop, what impact it may have on productivity and to test solutions. The perennial weeds; couch grass, creeping thistle and docks are increasing. These weeds are common problems in organic arable systems in northern Europe and it will be essential to better understand their biology to allow them to be managed to acceptable levels in a cost effective way.

Crop yields in 2000 on ten monitored organic Linked-farms were similar to Terrington apart from winter wheat which averaged only 3.5 t/ha compared to 6.7 t/ha at Terrington. Input costs, crop husbandry and sale prices were also similar to Terrington. The overall gross margins of the Linked-farms were lower than at Terrington, principally because of their higher proportion of fertility building crops and the general lower profitability of livestock enterprises. The need for more fertility building crops, the inclusion of livestock and lower wheat yields compared with Terrington are all functions of the lighter, less nutrient retentive soils on these farms. Compared to conventional Farm Business Survey data, the Linked-farms again showed a significant advantage in whole-farm gross margin (£980/ha vs. £625/ha).

The distribution of potato cyst nematodes (PCN) was mapped within all five plots in January 2001. PCN showed a similar distribution to sampling between 1998 to 2000 in OF0145 and there as was no evidence of a significant multiplication of PCN following potatoes. However, the growing of non-PCN resistant cultivars may have resulted in a more significant build-up and future research should consider the impact of variety choice on PCN infested land.

Technology transfer activities in 2001 were severely restricted by the FMD outbreak. However, results were presented at the DEFRA organic framing research review in Warwick in July 2001, at the COR conference at Aberystwyth in March 2002, and in the farming press.

The study has contributed data to several other DEFRA studies such as OF0164 – Understanding soil fertility in organically farmed systems, and OF0190 – Economics of organic farming.

A CSG7 proposal for a further extension to the project has been submitted to DEFRA. This concentrates on key sustainability measurements on the core study at ADAS Terrington.

Specific challenges deserving further study include:

- The ecology of perennial weeds and agronomic strategies for their control.
- Quantification of net nitrogen fixation by legumes and subsequent release to crops (covered by CTE 0204).
- The impact of potato cultivar on PCN multiplication.
- Effective management of slugs and potato blight.

Scientific report (maximum 20 sides A4)

Background.

This report covers a one-year period of a longer-term project, which began in 1990.

OF0102 - 1990 to March 1995
OF0112 - April 1995 to March 1998
OF0145 - April 1998 to March 2001
OF0301 - April 2001 to March 2002 (the subject of this report)

The project has evolved from a conversion study, to testing the sustainability of organic production. It has also contributed data to several other DEFRA organic farming studies such as OF0164 and OF0190.

Full reports (in addition to CSG12s) have been prepared annually for MAFF. As part of OF0301, two reports were presented for the 2000 harvest year; one on the linked-farm results, and one on the studies at Terrington. This CSG15 essentially reports one year of a long-term study and is best read in conjunction with the CSG15 for OF0145.

Introduction.

Results from OF0145 etc. showed that a stockless organic arable rotation was consistently more profitable than a conventional stockless crop rotation on the fertile silty clay loam soil at ADAS Terrington, at least when considering the first crop sequence after conversion. However, there were a number of challenges to sustaining that level of performance into the second crop sequence:

- The second and subsequent cycles follow only one rather than two years of clover. This will probably mean less nitrogen available to crops from atmospheric fixation and hence lower crop yields and profitability.

- Plant availability of other nutrients such as potassium and phosphorus may also become a future limitation. These nutrients have until now been available in sufficient quantity not to limit plant growth.

- In common with the experiences of most other organic farmers, weed levels are increasing, particularly creeping perennial weeds such as couch grass (*Elytrigia repens)* and creeping thistle (*Cirsium arvense*). These latter two are spreading and both have the potential to seriously reduce yields and crop quality.

- Pests and diseases have been a limitation to performance. Slugs in 1993 and 1998, and blight (*Phytophthora infestans*) in 1997 and 2000 reduced potato yields but the crops were still relatively profitable. Stem Nematode (*Ditylenchus dipsaci)* infested red clover in 1998 and severely reduced its growth. A change to the more resistant white clover has, so far, prevented a recurrence of the problem. There are a number of other pests and diseases, mainly soil borne, that have not yet been encountered but could become serious limitations. These include Potato Cyst Nematode (Globodera *spp.*) and Sclerotinia *spp*. If these developed they could necessitate a major change in the crop rotation and so affect profitability.

- The relative profitability of the organic rotation relies on substantially higher prices than for conventional crops. This is necessary to compensate for the lower saleable yields and for the 20% of the rotation in fertility building crops earning only a Set-aside payment.

Objectives.

The main scientific objective was to test the sustainability of an arable organic rotation, on a fertile soil, in the absence of grazing livestock or any inputs of animal manure (i.e. a "stockless" rotation).

1. *Assess the performance of a stockless organic arable rotation at ADAS Terrington.* Compare with Farm Business Survey data from conventional arable farms.

2. *Assess the performance of ten commercial, largely arable, organic farms and compare with Terrington.* (the "Linked-farms")

3. *Map the development and spread of perennial weeds in all 5 plots of the stockless rotation at Terrington.* The aim is to assess quantitatively the spatial distribution of these weeds and to monitor temporal changes.

4. *Compare cutting regimes for the clover fertility building crop for control of creeping perennial weeds.* Complete assessments on an experiment started in 2000.

5. *Potato Cyst Nematode*. Continue monitoring at Terrington to predict changes in PCN population through the rotation.

Design of the project.

To deliver the above objectives, the project is a combination of unreplicated large-scale system study, replicated small-plot research and monitored commercial farms.

Relevance to DEFRA policy.

This work contributes to DEFRA's policy objective of promoting a sustainable, competitive and safe food supply chain which meets consumers' requirements. It helps to identify sound methods of organic farming, limiting factors and ways of overcoming them. The aim is to maximise economic performance and in turn promote conversion to help realise the environmental and rural economy benefits that organic methods can deliver.

Objective 1. Assess the performance of a stockless organic arable rotation at ADAS Terrington.

Design and organic crop rotation

The core of the project is an unreplicated study with field-scale plots. Large plots were adopted to allow normal farm machinery to be used to get meaningful costings, to allow patchy problems such as perennial weeds and potato cyst nematodes to be encountered and researched, to give confidence to farmers that the system could work on a farm scale and to allow space for replicated small-plot experiments to be done in an organic context.

Conversion to UKROFS organic standard was achieved in 1995. Since autumn 2001, registration has been with the Soil Association. The crop sequence is:

- Vegetables (from 2001: split ⅔ potatoes and ⅓ calabrese)
- Winter wheat
- Spring beans
- Spring wheat (undersown)
- White clover (fertility building crop - Set aside)

In 2001, apart from clover, all crops were grown from organically produced seed or transplants.

When a plot was in vegetables, it was split ⅔ potatoes and ⅓ calabrese. The split is in a constant position so that potatoes and calabrese are always grown in the same areas of each plot. Calabrese was introduced from 1999 to evaluate an alternative to potatoes as a high-value cash crop in the rotation.

Layout

The 10ha of the experiment are divided into five approximately equally sized plots. The five-course rotation was phased-in over three years so that from 1997, each of the five plots was in a different crop. The full cropping history is shown in Appendix 1.

Conventional comparison

In OF0145 and before, performance was compared with the conventional crop performance at Terrington. Market changes and research needs have led to that rotation changing substantially, particularly when potatoes were no longer grown after 1998. Therefore, for OF0301 we proposed that conventional (non-organic) data instead be extracted from appropriate Farm Business Survey reports. However, FBS data for 2001 was not available in time to produce this report. As an alternative, data from the conventional crops at Terrington have again been used. Reports for any further extensions to OF0301 will include relevant FBS data for 2001 and subsequent years.

In 2001 the conventional rotation was:

- Sugar beet
- Winter wheat
- Winter wheat
- Winter beans
- Winter wheat

There was no conventional set-aside at Terrington in 2001.

Yield measurement

Organic crop yields in cereals and pulses were assessed using a plot combine; potatoes from machine harvested sub-plots; calabrese by hand cut and harvested sub-plots. Conventional crop yields were assessed from weighbridge data and sale records. This probably gave a slight advantage to the organic system due to the exclusion of poorer yields on headlands etc. Data from OF0145 shows that the difference in assessment method is relatively small, certainly less than 10%.

Crop and soil assessments were done separately on the parts of the plots which were in either potatoes or calabrese in the vegetable phase of the rotation. As the change from overall growing of potatoes in the vegetable phase was made only in 2001, data presented in this report are, unless otherwise stated, a mean of the assessments from the two areas in each plot.

Economic evaluation

All inputs to both organic and conventional crops were recorded and costed. Unless otherwise stated, all organic crops were sold as organic produce. Combined with the yield and crop value, a gross margin was calculated for each crop. Actual labour and machinery inputs were costed. Other fixed costs have been calculated from Farm Business Survey (FBS) data as the Terrington research farm does not give realistic values for these and they should be similar across farming systems. For comparison, the conventional rotation includes Set-aside but as this was not in the cropping at Terrington, standard figures have been used. As a final stage, the profitability of a model farm, of 120 ha, was calculated. Two models are presented, assuming that either potatoes or calabrese were grown; the data could be used to model the growing of both crops in various proportions. All appropriate AAPS payments have been included in the models.

Results

Fertility building crops

Legume fertility building crops were established by undersowing into the previous spring barley crop. In 2000, a mixture of large-leaved white clover cv. Aran (12.5 kg/ha) and lucerne cv. Vertus (6 kg/ha) was sown. As white clover has proved resistant to the current races of stem nematode present at Terrington, and lucerne did not contribute significantly to the sward, only white clover was sown in 2001 (2kg/ha each of Alice, Aberdai and Aran following advice from IGER specialists in Wales). In both years the clover was sown into the emerged barley crop; date of sowing (6 May 2000; 21 May 2001) was determined by barley growth stage, soil conditions and weather forecasts. The plots were rolled after sowing the legumes.

The clover/lucerne sown in 2000 grew well in 2001, with no evidence of pest or disease limitations. It was mown and left as a mulch four times between 31 May and 5 October. A final assessment was made on 20 December pre-ploughing. Above-ground gross accumulated nitrogen in the mulched legume in 2001 was good at 192 kg/ha (Table 1). However, this took no account of re-cycling, of below-ground accumulation or of losses so does not accurately reflect the net amount available for following crops. A better understanding of net N fixation by legumes, and how the nitrogen in these crops is subsequently mineralised would contribute to better rotation planning and better advice on how growers should respond to poor fertility crop performance. The new DEFRA project let under CTE02004 should help provide this information.

Table 1. Above-ground nitrogen (kg/ha) in the mulched legume fertility crop in 2001

Mulching date					
31 May	**03 July**	**12 August**	**05 October**	**21 December (pre-ploughing)**	**Total**
63	35	45	34	13	192

Crop yields

Whilst the weather in 2000/0 was ideal for clover growth, it caused problems for all other crops. Total rainfall in 2000 was 715mm, and in 2001 was 703mm compared to the 50-year average of 593 mm. Rainfall between September 2000 and April 2001 was particularly high with some months having double the long-term average. This led to very few days with the soil dry enough to travel on, or to work with machinery, increased leaching losses of nitrogen (not measured in this project) and delayed sowing into poor seedbeds. The summer of 2001 was also wet, particularly July. This led to ideal conditions for slugs and for potato blight. This was the most difficult year for organic production since the start of the project.

Winter wheat was sown on time in October 2000 and gave a reasonable yield of 5.96 t/ha (Table 2). This was below the 1993 to 2001 average of 6.5 t/ha, probably because of leaching losses of nitrogen in the wet winter and lower summer sunshine hours. Levels of cereal foliar disease were very low with none recorded in winter wheat at GS31 and only 2% severity of *Septoria tritici* on leaf 3 at GS75.

Table 2. Saleable crop yields (t/ha)

Crop	1998	1999	2000	2001
Potatoes, cv. Sante	14.66	19.26	28.77	18.80
Calabrese, cv. Marathon	4.83	8.83	8.95	0.00
Spring beans*	3.16	4.96	4.15	3.46
Winter wheat, cv. Hereward	7.93	7.07	6.66	5.96
Spring cereal**	3.95	2.98	5.32	3.64

* Beans cv. Scirocco in 1998 to 2000, cv. Maris Bead 2001.
**Wheat cv. Axona in 1998, barley cv. Derkado in 1999 and cv. Dandy in 2000 and 2001.

Sowing of spring beans and spring barley was not possible until mid April. Neither crop was affected by slugs and both gave near average yields. There was no disease on the beans until late July when moderate levels of rust developed, probably too late to significantly affect yield as the pods were already well filled. Maris Bead performed relatively well despite its low rating in the NIAB lists. It was not first choice; cv. Lobo was ordered but just before sowing we were informed that it no longer available. Maris Bead was the only alternative cultivar available. Spring barley was also virtually free of foliar disease with none found at GS33 or 59 and only 0.5% severity of *Rhyncosporium secalis* on leaf 3 at GS75.

Soil was not dry enough to plant potatoes until early May. Plants emerged and grew fast but were affected by increasing numbers of potato aphid (*Macrosiphum euphorbiae*) through late June and into July. Numbers peaked on 9 July with up to 60 aphids per leaf recorded. Much smaller numbers of peach potato aphid (*Myzus persicae*) were recorded. Heavy rainfall caused numbers to crash to zero by 24 July. Direct feeding damage was seen as necrotic spots and distortion of young leaves ("top-roll"). This probably reduced yield potential. Wet conditions in late July and into August led to blight symptoms appearing on 14 August (1% of pants affected). Blight remained at this level until 20 August when a copper fungicide was applied. Despite the fungicide, blight rapidly increased to affect 25% of plants by 24 August. This increase may have been less dramatic if it had been possible to apply the copper fungicide sooner. This was not feasible due to rain and wet soil conditions. Tops were removed mechanically by a flail mower on 27 August. Total yield was low at only 23.41 t/ha due to late planting, aphid damage and blight. Slugs thrived in the wet summer and caused damage to almost every tuber. In detailed grading of tubers from the sub-plots, saleable yield was only 7.2 t/ha. The crop was stored, refrigerated, in boxes. It proved impossible to find a buyer for the crop, due to an over-supply of organic potatoes, exacerbated by slug damage and an increasing level of silver scurf (*Helminthosporium solani*) during storage. They were kept until April 2001 when sprouting was starting and were then sold to the only market available which was for conventional processing. Actual quantity sold was 18.8 t/ha as the farm grading operation was less particular and allowed through tubers with very minor slug damage that were removed from the sub-plot grading. As this was significantly different to the test-plot results, and was the quantity actually sold, a yield of 18.8 t/ha has been used in the financial analyses.

Calabrese was transplanted on 3 May in good soil conditions. The plants were again covered with mesh from planting to exclude flying insects. Plants established and initially grew well in warm weather. However, on 14 May, 30.6mm of rain fell, saturating the soil. Slugs thrived in the wet and warm conditions and the first plant damage was seen on 15 May. By 21 May, 90% of plants had been eaten to ground level by the slugs. No organically grown plants could be found to re-plant the area. As an alternative to a fallow, the area was planted with potatoes cv. Sante on 25 May. These were also affected by blight and the foliage was removed using a flail mower on 29 August. Yield was low because of the very late planting. Sub-plot yield was only 12.8 t/ha total and 6.4 t/ha saleable yield. This additional potato crop has not been included in the economic modelling.

Economic performance

Where we have a direct comparison of crops at Terrington, organic saleable yields were 20% lower for winter wheat and 41% lower for potatoes (Table 3). This difference was mainly the result of potato yield losses from blight and slugs that were difficult to control organically.

Table 3. Organic *vs.* conventional yields, 1993 to 2001.

	2001 harvest			Rolling average		
	Organic (t/ha)	**Conventional (t/ha)**	**Difference**	**Organic (t/ha)**	**Conventional (t/ha)**	**Difference**
Potatoes	18.80	-		24.3	42.4	-43%
Calabrese	0.00	-		5.7	-	
Winter wheat	5.96	6.50	-36%	7.3	9.1	-20%
Spring cereal$^{\alpha}$	3.64	-		4.1	-	
Spring beans	3.46	-		3.5	-	
Oilseed rape	-	3.75		-	3.75	
Sugar beet	-	56.47		-	58.2	

α Excludes data on spring cereals grown following two-year red clover conversion crop during the phasing-in of the rotations.

The market for organic combinable crops has held over the period while conventional prices have fallen, notably for AAPS supported crops. This has led to a widening of the 'premium' for organic crops (Table 4). However, In 2001, no organic market could be found for potatoes due to the quality and marketing problems discussed above and the crop was sold for conventional processing for only £16/t in April 2002.

Table 4. Organic *vs.* conventional crop prices, 1993 to 2001.

	2001 harvest			Rolling average		
	Organic (£/t)	**Conventional (£/t)**	**Difference**	**Organic (£/t)**	**Conventional (£/t)**	**Difference**
Potatoes	16	-		254	107	137%
Calabrese	-	-		953	-	
Winter wheat	175	77	127%	185	83	123%
Spring cereal	170			176	-	
Spring beans	185	-		181	-	
Oilseed rape	-	138		-	138	
Sugar beet	-	28		-	32	

From 1993 to 2000, the conventional rotation had the lowest modelled whole-farm gross margin but due to the failure of the organic calabrese crop, and the failure to find a market for organic potatoes, the converse was true in 2001. On rolling average figures, organic still had the advantage in the modelled potato rotation (conventional gross margin was 55% of the organic rotation); the modelled vegetable rotation had a similar gross margin to the conventional rotation (Table 5). In practice, of course, an organic rotation is likely to include both potatoes and vegetables so the advantage over conventional would be intermediate between these figures.

The mean figures for the rotations were weighted to allow for the proportions of each crop in the totals. For the organic rotations it was 20% for each crop, for conventional it was 20% sugar beet, 12% oilseed rape, 40% first wheat, 20% second wheat and 8% set-aside.

Table 5. Gross margins for individual crops and for modelled crop rotations (rolling average figures from 1993).

	Organic (£/ha)		**Conventional (£/ha)**
	with potatoes	**with vegetables**	
Potatoes	4,849		-
Vegetables (mean of calabrese and onions)		1,301	-
Winter wheat	1,476	1,476	800
2^{nd} winter wheat	-	-	852
Spring cereal	715	715	-
Beans*	734	734	560
Sugar beet	-	-	1,412
Set-aside	68	68	183
Weighed average	1,568	859	855

* Spring beans in organic rotation, oilseed rape in conventional

When these gross margin data were modelled as 120 ha farms, higher allocated fixed costs for the two modelled organic rotations reduced the net margins more than for the conventional rotation (Table 6). Whilst the potato rotation still retained a substantial advantage to organic, the estimated Net Farm Income from the vegetable rotation was lower than conventional. This highlights how vulnerable organic returns are where a high margin cash crop is not grown, or fails.

Table 6. Net Farm Income for 120 ha model farms.

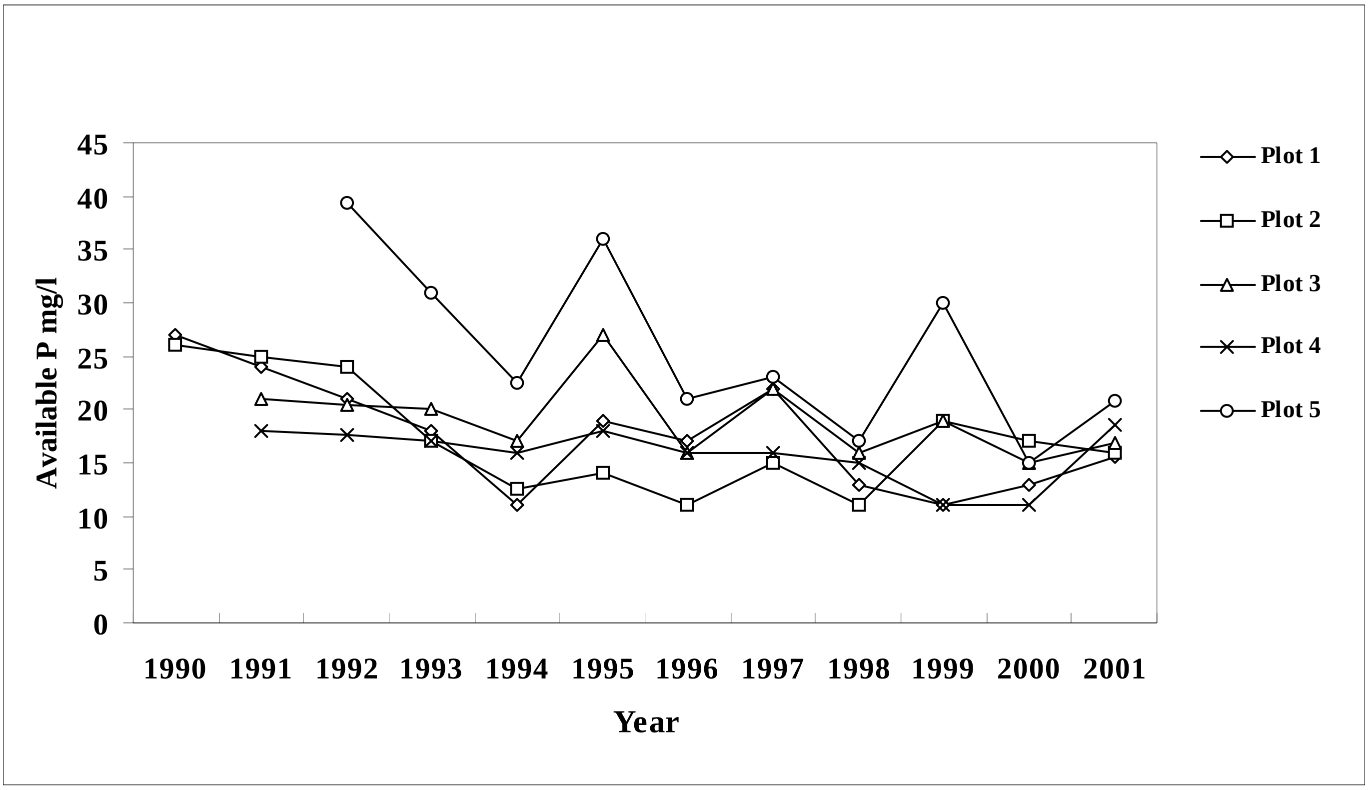
	Organic rotation with potatoes (£)	**Organic rotation with vegetables** (£)	**Conventional** (£)
Farm Gross Margin	188,160	103,080	102,600
Allocated fixed costs	32,280	44,640	24,840
Farm Net Margin	155,880	58,440	77,760
Other fixed costs **	66,000	66,000	66,000
Net Farm Income	89,880	-7,560	11,760
Difference from conventional	+78,120	-19,320	

** Cambridge University FBS 1999 data.

Changes in soil fertility

Soil available phosphorus (Olsen's method) declined markedly from 1990 to 1994 in all plots (Figure 1). In response to this decline, phosphorus fertiliser has been applied once per crop rotation, as Aluminium calcium phosphate ("Reddzlaag", 14 % P) at 625 kg /ha. Taking data from all plots, from 1990 to 2000, there was a significant negative correlation between soil P and year (y=24.1-0.935x, p-value 0.001, R squared (Adjusted) 0.186). There is an indication of a reduced rate of decline since 1995 but more data are needed to confirm that trend. By autumn 2001, soil available P averaged 17.5 mg/l which equates with the top end of ADAS Index 1, well above deficiency levels. A full nutrient balance has been done as part of project OF0114. This predicted a near balance in P when the rotational application of Reddzlaag was included, so that has been continued. Season variations have been evident but are not unexpected as the soil available P will be a function of offtake in the previous crop, and release from organic matter by biological processes. These two will be influenced by environmental factors such as rainfall and soil temperature. The result is likely to be more variable between years than where inorganic P or manures are added to soil.

Figure 1. Soil available P.



Soil available potassium levels (ammonium nitrate method) have also shown some very marked variations between seasons, although there has been a general downward trend (Figure 2). As for P, a relatively large variation between years is not unexpected, due in the case of potassium to variability in crop offtake, release from clay minerals, and leaching losses. Levels in autumn 2001 were between 128 to 186 mg/l, the lower end of ADAS Index 2. The nutrient balance done in OF0114 shows a large annual average negative balance of 53 kg/ha. As for P, taking data from all plots, from 1990 to 2000, there was a significant negative correlation between soil K and year (y=211-6.6x, p-value 0.003, R squared (Adjusted) 0.154). However, as for P, there is also a trend towards a slower rate of decrease in recent years and soil available K remains adequate. Future trends in both P and K are key elements of the sustainability of the stockless rotation.

Soil organic carbon has shown a relatively constant value, across all five plots, of between 1.2 to 1.7 % (Figure 3). However, the values for plots 1 and 3 in 1995 were markedly higher at around 2.5 %. The consistency of the other data suggests that these were not real treatment effects although careful investigation has not revealed any obvious source of error. Data in the early years of the project was derived from single soil samples, bulked from a number of sampling points within each plot. Since 2001, each plot has been sampled and analysed in six discrete blocks. This will give more confidence in the results. The lack of change in soil carbon is not unexpected, as the returns of organic matter will not be a lot greater than in the previously practised conventional arable rotation. The clover fertility crops are a new source but these will be to some extent balanced by lower crop yields and hence smaller crop residue returns to the soil.

Figure 2. Soil available K.

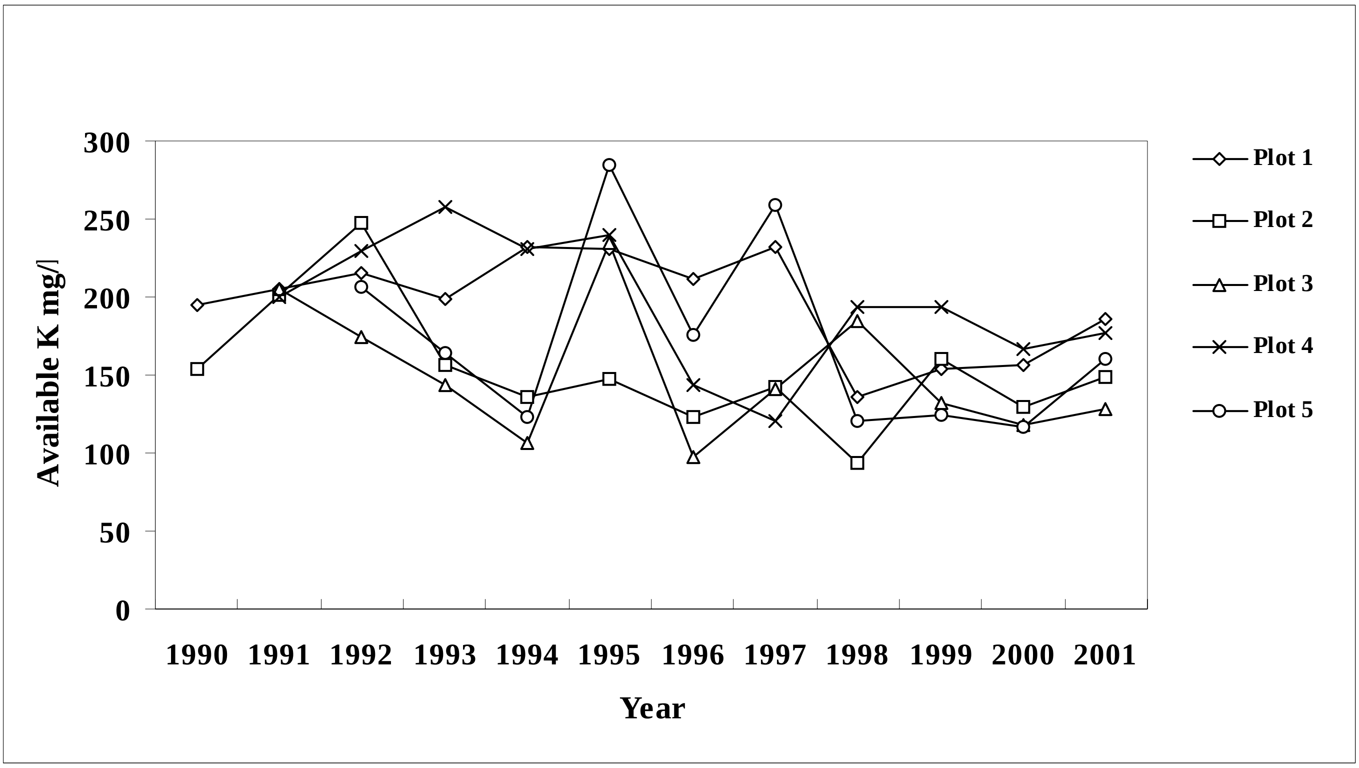
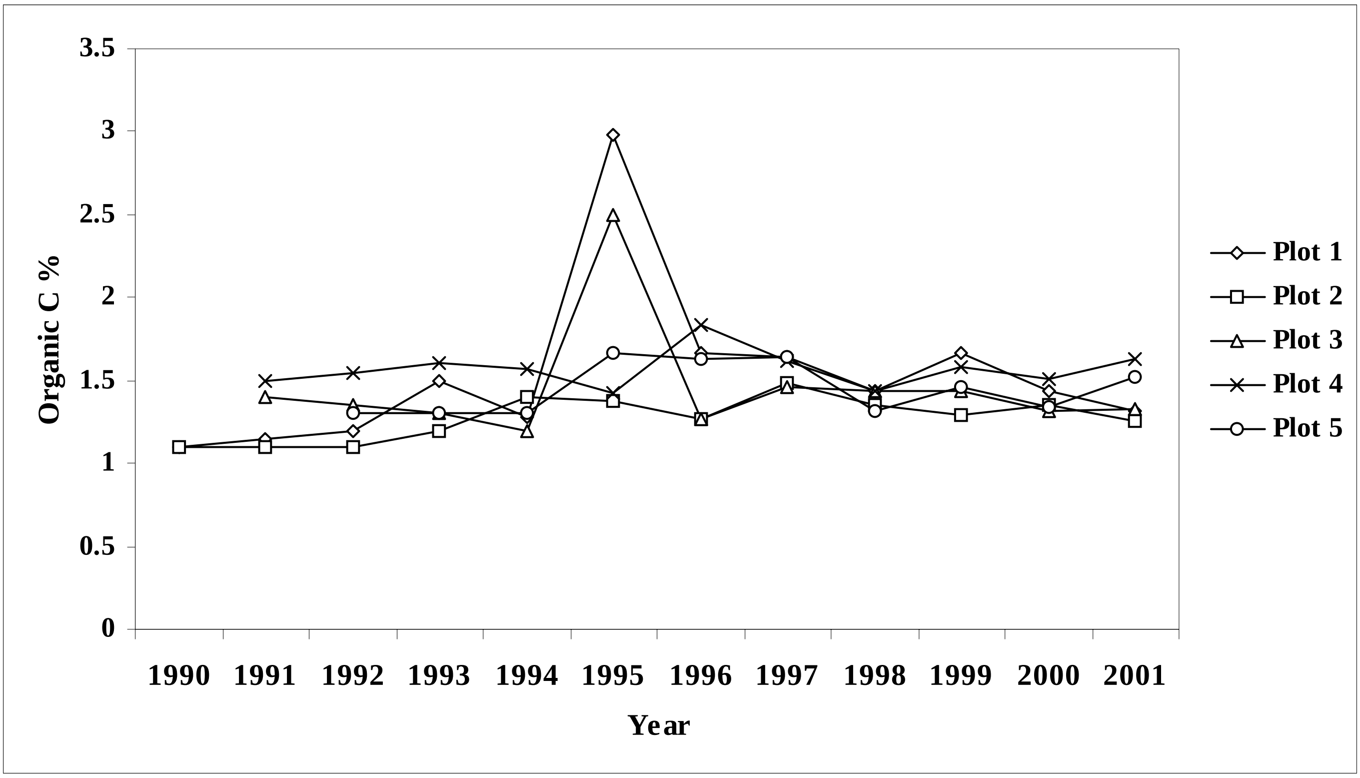


Figure 3. Soil Organic Carbon %.



Nitrogen balance is more difficult to predict due to the difficulty in knowing what the net N fixation by leguminous crops has been. MAFF project OF0178 has reviewed this and calculated the balance for the Terrington rotation using the latest published data. Using actual data for crop N offtakes and legume dry matter production, this showed that the rotation was very close to a balance. The lack of any progressive decline in crop yields would support this calculation. There will be variation as when stem nematode affected growth in 1998 and a failed clover crop was replaced by vetch in 1999, but essentially the rotation is probably in balance for nitrogen.

Objective 2. Assess the performance of ten commercial, largely arable, organic farms and compare with Terrington. (the "Linked-farms")

Due to the time needed to compile full business accounts, the Linked-farm results in this report are for year 2000.

In project OF0145, during 1998, one of the original group of ten farms withdrew from the project. A further farm was lost following the sale of the farm during 2000. Unfortunately a third farm was also lost due to sale in 2001, leaving just seven for analysis for year 2000. Efforts were made during 2000, and into 2001 to recruit replacement farms. However, we found resistance to involvement by some key targeted farmers and movement restrictions following outbreak of Foot and Mouth Disease in February 2001 made progress impossible.

Of the seven farms, four were costed to a net farm income level; three could be costed only to farm gross margin level due to the incorporation of unrelated businesses in their accounts. The results were compared with equivalent conventional farms from the Nottingham University Farm Business Survey (FBS), and with organic results from Terrington.

The weather in 2000 caused problems with timeliness of planting, harvesting and weed control. As a result, Linked-farm crop yields were lower than in recent years for most crops. Crop yields were generally less than at

Terrington, with the greatest difference in winter wheat; the Linked-farm average of 3.5 t/ha was almost half the Terrington average of 6.7 t/ha.

Whole-farm margins were of course also influenced by the proportionate mix of enterprises and fertility building crops on individual units. The most profitable farms were again those growing the higher gross margin crops such as potatoes and/or vegetables. The latter had the advantage in 2000 of a still under-supplied market and good premiums over conventional price. Livestock prices have improved over the period but livestock enterprises continue to return relatively poor financial performance.

In 2001, the financial performance of the Linked-farms was again significantly lower than in the OF0145/0301 core project at Terrington (Table 7). Crop varieties, agronomic practices, variable inputs and prices received for sales of produce have been broadly similar. There are two principal reasons for the difference. First, the silty clay loam soil at Terrington is more retentive of water and nutrients. This allows a higher proportion of cash crops to fertility building crops to be grown, which along with the intrinsic fertility of silt soils leads to higher crop yields. Secondly, the higher proportion of fertility building crops on the Linked-farms is utilised by livestock, and livestock enterprises have been less profitable than crops, although the gap is closing.

Table 7. Farm gross margins for Linked-farms, Terrington and FBS conventional farms.

	Farm Gross Margin £/ha					
	1995	**1996**	**1997**	**1998**	**1999**	**2000**
Linked-farms	1228	964	925	1295	1397	980
Terrington*	1680	2271	1818	1748	1708	1453
FBS conventional**	1049	851	680	768	696	626

* Average of the organic rotations.
**University of Nottingham

Whilst Linked-farm margins have generally been sustained (Table 8), conventional farm profitability has fallen sharply since 1995, mainly due to lower prices. For example, by 2000 the FBS Net Farm Income was only £17/ha.

Table 8. Linked-farms Net Farm Income (4 farms).

	Net Farm Income £/ha					
	1995	**1996**	**1997**	**1998**	**1999**	**2000**
Output	1571	1351	1291	1641	1744	1264
Variable costs	343	387	366	346	346	285
Gross Margin	1228	964	925	1295	1397	980
Fixed costs	637	688	736	780	820	774
Net Farm Income	591	276	189	515	576	206

Linked-farms percent organic conversion in 2000 averaged 64% (range 3 to 100%)

Fixed costs varied greatly between farms reflecting the different levels of capital investment for different enterprises. There was limited variation between similar types of business but these were often associated with the individual nature of the businesses and the priorities of the owners. The average level of fixed costs was higher than the comparative group of conventionally managed FBS farms but the four farm sample was too small and varied to draw firm conclusions.

Objective 3. Map the development and spread of perennial weeds.

From 1998 to 2000, changes in the spatial distribution of couch grass (*Elytrigia repens*) were measured in plot 4 of the stockless rotation at Terrington. A nested sampling plan was designed with 101 sampling points. Each point was located by GPS and also physically on the site. At each sampling point, shoots of couch were counted in a 1 m^2 quadrat. Couch grass shoots were counted on five occasions from 1998. Couch was persistently present in less than 10% of quadrats and spread was relatively slow. However, as reported in the CSG15 for OF0145, shoot numbers were apparently influenced by crop and cultivations suggesting that it should be possible to derive improved management guidelines for couch control in arable organic systems. To gain better information to test this, for OF0301, the mapping was extended to all five plots and, for plot 4, the sampling points were re-arranged to better map the very localised couch patches. Perennial weeds were counted in June and in December 2001 (Appendices 2 and 3). Throughout the project, plot 4 has visibly had a much more widespread distribution of couch; in the other four plots it was generally limited to the margins. Where couch was present, shoot density was much greater in plot 4, at up to 180 shoots per m^2; the other plots had densities of less than 60 shoots per m^2, and at most points it was less than 10 shoots per m^2. These differences have been obvious since the start of monitoring in 1998 and are probably related to the previous cropping and management of the field. It is not possible to directly compare the 2001 and 1998-2000 data for plot 4 as the sampling plan was changed for 2001. The intention was to collect data from all five plots over at least three seasons to determine whether there are links between cropping and cultivations and the presence and density of couch. The one-year data presented in this report is, on its own, of limited value as it represents a snapshot of weed population and density. Assessments over a longer time period would be necessary to draw conclusions about effects of crops and cultivations on couch grass survival and density. Detailed weed mapping is not part of the core assessments in a CSG7 continuation proposal; however a concept note has been submitted to DEFRA for a project which would continue these assessments as part of a subsidiary project.

Objective 4. Compare cutting regimes for the clover fertility building crop for control of creeping perennial weeds.

This experiment was within plot 4 of the stockless with vegetables rotation at Terrington (see CSG15 for OF0145). Plot 4 was undersown with white clover (*Trifolium repens*, cv. Arran) and lucerne (*Medicago sativa*, cv. Vertus) in spring wheat in 1999. The site was chosen as it had an even population of creeping thistle and was in clover/lucerne in 2000. The hypothesis was that frequency and timing of mowing of clover can affect creeping thistle shoot number.

Treatments

1. Cut when thistle flower buds visible.
2. Cut when clover/lucerne reaches 45 cm height.
3. Cut every 2 weeks from June until the end of September.

Design and assessments

Design was five replicates of three treatments in a randomised block design. Plots size was 23 m × 4 m (width to fit in with two passes of a 2 m wide tractor rear-mounted flail mower). Mowings were left as a mulch. Thistle shoot numbers were counted in ten fixed quadrats, each of 1m^2, in each plot. The quadrats were located in two lines along the length of each plot and 0.5 m from each edge to avoid the tractor wheelings from mowing. Counts were made in April 2000 before treatments were applied, and again in July 2001 in the following calabrese crop. The change in thistle shoot numbers between the two assessment dates was analysed using Analysis of Variance.

Results and discussion

Legumes established and grew well. The sward was dominated by white clover with only around 10% ground cover from lucerne in May 2000. The contribution from lucerne decreased to around zero by September so the results essentially apply to a white clover sward. Apart from occasional docks (*Rumex obtusifolius*), the only weed present was creeping thistle. First mowing was on 30 May. Treatment 1 was mown three times; treatment 2, four times; and treatment 3, eight times. Thistle shoot numbers showed a marked decrease between April 2000 and July 2001 in all three treatments, with the size of the decrease similar across the treatments (Table 9). There were no significant differences between the treatments. The results suggest that, within the time frame considered, achieving and maintaining a dense competitive crop had more influence than mowing frequency on creeping thistle survival under a clover fertility-building crop.

Table 9. Creeping thistle shoot numbers.

Treatment	Thistle shoots (No. per m^2)		Change
	April 2000	**July 2001**	
Mown when thistle flower-bud visible	10.28	2.94	-7.34
Mown at a legume height of 45 cm	9.24	2.38	-6.68
Mown every two weeks	8.82	1.94	-6.88
SE (8df)			1.575
P			0.970 (NS)

Objective 5. Potato Cyst Nematode monitoring.

The distribution of potato cyst nematode (PCN) within the five plots of the stockless organic rotation at ADAS Terrington has been mapped annually, in winter, since December 1998. Each of the five plots was divided into sub-plots of approximately 625 m^2 (25 x 25 m). The corners of each sub-plot were geo-referenced using a GPS (Global Positioning System) to record actual location and aid relocation. On each sampling occasion, 30 soil cores were taken to 15 cm depth from each sub-plot and bulked to make one representative sample for each sub-plot. PCN cysts were extracted and egg counts made using standard assessment methods.

The PCN population levels observed over the four cropping years covered by the sampling occasions remained at low levels (Table 10). Variations in the percentage of plots infested, and PCN eggs/g of soil in individual plots, were within the range of sampling errors that would normally be encountered when assessing low PCN populations. Critically, there was no evidence of a significant multiplication in the PCN population in plots cropped with potatoes prior to a sampling occasion (Table11). None of the PCN populations found were sufficiently numerous or viable for a PCN species test to be done. However, the fact that the potato variety grown in all plots was Santé, which has full resistance to both yellow PCN (*Globodera rostochiensis*) and partial resistance to white PCN (*Globodera pallida*), would have contributed significantly to suppressing the build-up of PCN populations.

Table 10. Percent of sub-plots infested and range of PCN populations found on each sampling occasion.

Measure of infestation	**Sampling date**			
	December 1998	**January 2000**	**January 2001**	**December 2002**
% sub-plots with no cysts found	87.9	92.4	87.3	83.4
% sub-plots with very low PCN levels (non-viable cysts)	5.7	2.5	5.1	9.5
% sub-plots with low PCN levels (viable cysts)	6.4	5.1	7.6	7.0
Range of eggs/g soil	0.03 – 4.1	0.05 – 4.6	1.0 – 7.0	1.0 – 5.0

Table 11*.* Percent of sub-plots containing viable PCN cysts for each sampling occasion in relation to potato cropping history (bold figures for plots 1, 2, 3 and 4 indicate samples taken in the winter immediately following a potato crop).

Plot	**Number of sub-plots**	**Last potato harvest year**	**% sub-plots with low PCN levels (viable cysts)**			
			December 1998	**January 2000**	**January 2001**	**December 2001**
1	32	1998	**6.3**	0.0	9.4	9.4
2	31	2000	6.5	0.0	**3.2**	0.0
3	33	1999	0.0	**6.1**	3.0	0.0
4	26	2001	19.2	15.4	19.2	**19.2**
5	35	1997	2.9	5.7	5.7	8.6
Mean	31.4	-	6.4	5.1	7.6	7.0

Small differences were seen in the PCN counts between different plots (Table 11), with plot 4 consistently having a higher population than the other four plots. From 1998 to 2000, as reported in OF0145, there were distinct, and largely temporally persistent, foci of PCN in the eastern part of plot 4 and the north-west and south-west corners of plots 1 and 2 respectively. These infested areas probably reflected the general location of initial foci of PCN infestation rather than an impact of the recent cropping history. A map showing the spatial distribution of the cysts in December 2001 is included in appendix 4. This shows similar foci of PCN to those found from 1998 to 2000 and confirm that PCN population is not changing significantly under the current frequency of one year in five of potatoes whilst growing the resistant variety Santé. Therefore, it is not proposed to continue PCN mapping in this form in any extension of the project. However, the use of non-PCN resistance varieties may well have resulted in more significant population build-up and future work should consider the impact of variety choice on the sustainability of organic potato cropping on PCN-infested land.

Technology transfer

The FMD outbreak prevented any technology transfer events at Terrington during 2001 and severely restricted other opportunities. Events that took place were:

- A presentation at the DEFRA Review of Organic Farming at Warwick University in July.
- Two presentations at the COR 2002 Conference in March 2002 – details below.

Publications and press articles resulting from the project

Anon (2002) Stockless system can work. *Farmers Weekly*, 8-14 Feb 2002.

Cormack, W. F. (2002) Effect of mowing a fertility-building crop on shoot numbers of creeping thistle (*Cirsium arvense* (L.) Scop.) in *Proceedings of the UK Organic Research 2002 Conference*, 26-28 March 2002, Aberystwyth, 225-226.

Welsh, J. P., Philipps, L. & **Cormack, W. F.** (2002) The long-term agronomic performance of organic stockless rotations in *Proceedings of the UK Organic Research 2002 Conference*, 26-28 March 2002, Aberystwyth, 47-50.

Possible future work

A CSG7 has been submitted to DEFRA for the continuation and further development of the core assessments at Terrington. This focuses on key assessments of sustainability and also maintains a monitored site for other related studies.

Appendices

Appendices presented to DEFRA with this report:

1. Details of the organic crop rotation.
2. Mapping of couch grass presence.
3. Mapping of couch grass shoot density.
4. Mapping of Potato Cyst Nematode.
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