PROJECT REPORT No. 307

ORGANIC CONVERSION STRATEGIES FOR STOCKLESS FARMING

JULY 2003

Price £4.75

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by

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This the final report of a 36 month project that started in March 2000. The work was funded by a grant of £94,583 from HGCA (project 2313).

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ABSTRACT

Legume-containing leys are used to improve soil fertility in the two-year organic conversion period. While in-conversion land may be grazed, it is effectively out of production in stockless farming systems, potentially resulting in a reduction in income and pressure on cash flow. The effects of seven conversion strategies on a subsequent organic winter wheat crop were investigated on a sandy loam and a sandy clay soil. Experimental data were then used in a mixed integer programming model to examine the effects of whole-farm conversion on farm profitability. The strategies were: 1. two-years' red clover-ryegrass green manure, 2. two-years' hairy vetch green manure, 3. red clover for seed production, then a red clover-ryegrass green manure, 4. spring wheat undersown with red clover, then a red clover green manure, 5. spring wheat, then winter beans, 6. spring oats, then winter beans, 7. spring wheat undersown with red clover, then a barley-pea intercrop.

In-conversion crop yields were generally low and undersown wheat failed completely. Conversion strategies had a significant impact on organic wheat yield, which ranged from 2.8 to 5.3 t ha^{-1}. This was attributed to differences in organic wheat establishment, caused by variation in soil structure due to the different conversion strategies. Organic wheat yield was not related to weed abundance or soil mineral nitrogen.

In the absence of a specialised clover seed market, two years' red clover-ryegrass was the best conversion strategy for a risk-averse individual, due to the subsequent income from the high-yielding organic wheat. Growing oats followed by beans was a medium risk, medium return option, useful when labour supply is limiting and stable cash flow a priority. However, such a strategy may not currently qualify for organic farming scheme payments. Given current prices and experimental yields, investments were always recouped and should not necessarily deter growers from conversion. On a 250 ha farm with (without) current subsidies, organic prices could fall by 26% (34%) before organic and conventional production were equally profitable.

A relaxation in the requirement for fertility-building phases during conversion, the expansion of domestic red clover seed production and the development of the market for in-conversion produce are recommended.

SUMMARY

Introduction

The demand for organic produce in the UK currently exceeds supply (Lampkin & Measures, 1999) and it has recently been estimated that 70% of organic produce sold in the UK is imported. Organic farming is largely limited to mixed farming systems which use fertility-building leys and animal manure to enhance soil fertility. However, many UK farms are exclusively arable and it would not be feasible for these units to incorporate animals into the system in order to convert to organic production (Lampkin, 1990). If these farms are to convert to organic status then stockless organic systems need to be developed. Moreover, as the number of livestock-based organic farms continues to grow there will be an increasing market for organic cereals for livestock feed.

Organic farming systems are more dependent on the structure and nutrient status of the soil than conventional systems. In a stockless organic rotation, the system relies on biological nitrogen fixation and incorporation of crop residues to replenish nutrients taken off when crops are harvested. Therefore, fertility-building and fertility exploitative phases of the rotation must be carefully balanced to achieve a sustainable system. In addition, the organic matter content of the soil will influence its stability and water holding capacity. Work at Elm Farm Research Centre (Bulson *et al*., 1996) has shown that stockless organic systems, using red clover as a green manure to build fertility, can be economically and agronomically viable. They also highlighted the importance of rotation design to maintain agronomic performance. However, work to date has focused on the rotation once organic status has been achieved rather than the optimum choice of cropping during the conversion period.

The economic implications of converting to a stockless organic system depend upon the relative prices of organic and conventional produce and the risk associated with different conversion strategies. By choosing to convert to organic production growers are making an investment decision, offsetting current revenue for future returns, with the level of investment determined by the costs of conversion. In addition, cash flow implications for the business will influence the choice of conversion strategy. It is important that any research that examines the implications of converting from conventional to organic production takes into account these economic implications to provide growers with sufficient information to make informed choices about their agronomic and business management practices.

Conversion strategies are also influenced by current policy decisions as part of the European Union's Common Agricultural Policy (CAP) and DEFRA's Organic Farming Scheme (OFS). A favoured conversion strategy has been a two-year fertility building ley, such as red clover, which is cut and mulched to provide a green manure. This has been popular because growers could claim both set-aside payments and organic aid payments. However, there is uncertainty over the total amount of money available under the OFS and reliance upon set-aside rates and payments is at the discretion of the European Commission. For example, although set-aside is fixed at 10% until 2006, the Commission can alter this rate at its discretion. Therefore it is necessary to consider the economic implications of different conversion strategies both with and without the policy support of set-aside payments and organic conversion grants.

The economics of organic farming have received considerable attention (e.g. Murphy, 1992) although at times such studies have been criticised for examining small-scale 'part-time' holdings (Bateman, 1993). Moreover, much research into the economics of organic production has focused upon the performance of the farm system once organic status has been achieved or the research has examined the performance of converting farms that typically include vegetable crops within the rotation (Nieberg and Schulze Pals, 1996). However, there is a lack of empirical research into the economics of converting to stockless organic systems that produce mainly combinable crops, despite evidence to suggest that there is a growing market for organic cereals and pulses (Leake, 1999).

Aims and Objectives

Overall aim:

To recommend a number of appropriate conversion strategies for stockless organic rotations both under Agenda 2000 and further policy reform.

Specific Objectives:

- To monitor, in detail, the changes in soil structure and nutrient status that occur when different conversion strategies are imposed and to assess their effect on subsequent cropping.
- To assess the impact of different conversion strategies on profit, risk, return-on-investment and cash flow.
- To provide a practical guide to aid growers in their decision making when choosing a conversion strategy.

Materials and Methods

<u>Field experiments</u>

A large-scale field experiment was established at Bunny Park Farm, University of Nottingham. The experimental area (approximately 1.5ha) was located within a 20ha block of land that was entered into organic conversion on 1 August 1999. A red clover/ryegrass mix was sown on the entire area on 4 September 1999, to prevent nitrate leaching over the winter period and to form the starting point for the different conversion strategies. The soil was sampled in October to provide a baseline measurement of N, P, K and organic matter. The experimental plots (approximately 30m *12m) were laid out in a randomised block design with four replicates. In March 2000, spring-sown crops identified for year 1 of a conversion strategy were established (Table 1). The soil texture on the experimental site fell into two broad categories of sandy loam (blocks 1 and 2) and clay loam (blocks 3 and 4), and was in the Dunnington Heath series.

Table 1. The conversion strategies were two-year cropping sequences, all followed by wheat in the third year. † A cut and mulched green manure; u/s = undersown with red clover.

Strategy	First Year Conversion		Second Year Conversion
RCRC	† red clover-ryegrass	-	† red clover-ryegrass
VEVR	† hairy vetch	-	† hairy vetch-rye (cv. Motto)
CSRC	red clover (seed) –ryegrass	-	† red clover-ryegrass
UWRC	u/s spring wheat (cv. Paragon)	-	† red clover
WHBE	spring wheat (cv. Paragon)	-	Winter beans (cv. Clipper)
OABE	spring oats (cv. Solva)	-	Winter beans (cv. Clipper)
UWBP	u/s spring wheat (cv. Paragon)	-	spring pea (cv. Agadir) - spring barley (cv. Static)

During the conversion period the nutrient cycling within each crop was monitored and crop growth, development and yield was assessed. In the third year of the experiments, a crop of winter wheat (cv. Hereward) was established across the entire experimental area to assess the effect of the different strategies crop yield and quality once organic status had been achieved. In addition, soil physical and chemical properties were monitored throughout the first organic cropping season.

Economic analysis and farm level modelling

The results of the experimental work were used to examine the economic implications of different conversion strategies. The economic implications of conversion encompass four main factors: profitability, risk, return-on-investment and cash flow. To examine these four factors a farm-level, multiperiod MIP (mixed integer programming) model was constructed (using Premium Solver in Microsoft Excel) to simulate a stockless farm undergoing organic conversion. The objective of the model is to find the optimum farm cropping strategy during the conversion period on the basis of maximized profit, measured as farm net margin[1] (FNM). The model describes an arable rotation over an eight-year period that encompasses organic conversion. The farm undergoes a ‘staggered’ organic conversion whereby a quarter parcel of arable land enters conversion every year for four years. The two-year conversion period for each parcel of land means that it takes five years for the whole farm to convert to organic production. The model begins with a conventional ‘base year’, which describes the farm before conversion, with the conventional rotation: winter wheat, second wheat, winter barley, oilseed rape/set-aside (Table 2). The model also includes year 0, the last conventional year before conversion.

Table 2. A diagrammatic representation of the crop rotation before (Base Year and year 0), during (Years 1-5) and after (Years 6 and 7) organic conversion. The shaded areas highlight the organic conversion period for each quarter of converting land.

	Base Year	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**
Quarter A	WW1	WW2	C1	C2	OW*	OB	OO	OCl	OW
Quarter B	OSR/ SA	WW1	WW2	C1	C2	OW*	OB	OO	OCl
Quarter C	WB	OSR/ SA	WW1	WW2	C1	C2	OW*	OB	OO
Quarter D	WW2	WB	OSR/ SA	WW1	WW2	C1	C2	OW*	OB

WW1= conventional 1st winter wheat
WW2= conventional 2nd winter wheat
WB= conventional winter barley
OSR= conventional oilseed rape
SA= set-aside
C1= first year of conversion strategy
C2= second year of conversion strategy
OB= organic winter beans
OO= organic winter oats
OCl= organic clover-ryegrass green manure
OW*= organic winter wheat after conversion period
OW= organic winter wheat.

In year 1 the first quarter of land, quarter A, enters organic conversion (Table 2). The land enters conversion in the place of the winter barley crop in the conventional rotation. This ensures that the two most profitable crops in the conventional rotation, the two winter wheat crops, are cropped for as many years as possible in an attempt to boost farm net margin. Converting land may be cropped using one or more of the strategies examined in the field experiment, that is, the quarter parcel of land may be divided between strategies, if it is most profitable to do so. In year 2 quarter A enters the second year of conversion, and quarter B enters the first year of conversion. The four quarters of land may use the same conversion cropping strategy as each other, or entirely different strategies from one another. After the two-year conversion period the land starts the organic rotation: OW*, winter beans, winter oats, clover-ryegrass green manure. The different conversion strategies were shown in the

[1] Definition: Gross output minus labour and machinery costs, minus rent.

field experiment to influence the yield of the subsequent OW* crop. To account for this effect the model uses different input data for this crop, depending upon which conversion strategy preceded it. In this way whilst the organic rotation following conversion is always the same, the economic performance of the OW* crop will change with conversion strategy choice. It is assumed that different conversion cropping strategies only influence the yield of the first crop of the organic rotation. Thus, data for the remaining organic crops in the model (OB, OO, OCl, OW) do not change with different conversion cropping strategies. In year 6 the whole rotation becomes fully organic.

Results and Discussion

Organic wheat crop performance

There was a significant effect of conversion strategy on OW* grain yield (Table 3; *P*=0.002). OW* following the three 'clover strategies', (containing a red clover green manure in the second year: RCRC, CSRC and UWRC) had the highest yields. These 'clover strategies' all produced greater yields than the UK average for organic wheat of 4 t ha^{-1} (Lampkin, Measures and Padel, 2002). The remaining strategies produced yields below this average. OW* yield following RCRC was similar to, or slightly lower than those attained in other stockless organic rotation experiments following two years' red clover-ryegrass: 5.2 t ha^{-1}, 6.0 t ha^{-1} (Stopes, Millington and Woodward, 1996; Cormack, 1996). OW* yield following RCRC was also similar to the yield achieved by the variety Hereward, 5.6 t ha^{-1}, when grown organically after one years' red clover-ryegrass green manure (Thompson, Gooding and Davies, 1993). Yields of wheat after winter beans compared favourably with previous reports of 4.05 t ha^{-1} (Bulson, Welsh, Stopes and Woodward, 1996).

Greater yields were produced on sandy soil than on clay soil. Although this difference in yield between soil textures was not significant (*P*=0.064), there was a significant interaction between soil texture and conversion strategy (*P*=0.024), such that wheat following WHBE and OABE performed much worse on the clay soil than sandy soil, compared to the other strategies. Wheat following WHBE and OABE had the most variable yields of all strategies, while wheat following CSRC had the least variable yield. The differences in yield between conversion strategies were mainly caused by variation in plant population. Establishment was poor at the 'clay' end of the experiment, particularly following the WHBE and OABE conversion strategies. This was related to the soil structure on those plots (Table 4) which, together with soil texture, explained 89% of the variation in plant population.

Table 3. Combine harvested grain yields (t ha^{-1}) (85% DM) of organic wheat crop as affected by conversion strategy and soil texture.

Conversion strategy	Sand	Clay	**Mean**
RCRC	6.07	4.49	**5.28**
VEVR	4.78	2.18	**3.48**
CSRC	5.14	3.92	**4.53**
UWRC	4.99	3.55	**4.27**
WHBE	5.11	1.05	**3.08**
OABE	5.64	1.12	**3.38**
UWBP	3.90	1.74	**2.82**
Mean	**5.09**	**2.58**	

	P value	SED	df
Conversion strategy	0.002	0.475	12
Soil texture	0.064	0.665	2
Conversion strategy *soil texture	0.024	0.911	6.24

Table 4. Visual soil structure scores recorded in March 2002 in OW*, as affected by conversion strategy and soil texture. Structure is scored on a scale of 1-10 where 1 = very big clods, smooth dense crack faces, reducing conditions, roots only in cracks; 10 = entirely porous crumbs.

Conversion strategy	Sand	Clay	**Mean**
RCRC	7.29	6.21	**6.75**
VEVR	6.50	5.50	**6.00**
CSRC	6.71	6.21	**6.46**
UWRC	6.29	5.93	**6.11**
WHBE	6.50	5.00	**5.75**
OABE	6.57	5.00	**5.79**
UWBP	6.00	5.57	**5.79**
Mean	**6.55**	**5.63**	

	P value	SED	df
Conversion strategy	0.062	0.326	12
Soil texture	0.074	0.265	2
Conversion strategy *soil texture	0.371	0.502	12.16

Conversion strategy had a significant effect on soil mineral nitrogen (SMN) available to the wheat crop (Table 5) but, once the differences in plant population were accounted for, SMN did not explain a significant proportion of the variation in yield. There were large differences in weed density within the organic wheat crop, but there were no significant differences between conversion strategies. This was surprising given the significant differences observed during the conversion period. There was no significant relationship between weed density and yield, thus weed density either had no impact on wheat yield, or the overriding effects of plant population masked any such impact.

Table 5. SMN (kg ha^{-1}) in September 2001, February 2002 and September 2002, as affected by conversion strategy and soil texture.

Conversion strategy	September 2001			February 2002			September 2002		
	Sand	Clay	**Mean**	Sand	Clay	**Mean**	Sand	Clay	**Mean**
RCRC	57.4	38.3	**47.8**	120.3	50.5	**85.4**	44.3	31.1	**37.7**
VEVR	84.3	20.1	**52.2**	97.5	38.0	**67.7**	32.0	14.1	**23.0**
CSRC	36.9	25.5	**31.2**	143.9	53.2	**98.6**	43.4	24.0	**33.7**
UWRC	41.6	47.0	**44.3**	114.4	67.1	**90.7**	42.2	24.8	**33.5**
WHBE	40.4	39.3	**39.8**	80.2	40.2	**60.2**	18.0	12.3	**15.2**
OABE	71.0	36.8	**53.9**	86.2	52.0	**68.6**	16.6	12.0	**14.3**
UWBP	34.5	27.0	**30.8**	63.6	49.0	**56.3**	18.6	19.6	**19.2**
Mean	**52.3**	**33.4**		**100.9**	**49.8**				

	September 2001			February 2002			September 2002		
	P value	SED	df	*P* value	SED	df	*P* value	SED	df
Conversion strategy	0.007	5.79	12	0.022	11.64	12	< 0.001	4.42	12
Soil texture	0.053	4.54	2	0.020	7.27	2	0.107	3.92	2
Conversion strategy *soil texture	< 0.001	8.84	12.51	0.105	16.88	13.8	0.224	7.00	11.21

<u>Economic analysis</u>

Averaged over the three years of study CSRC had the highest mean annual gross margin of £696 ha^{-1}, (Table 6) due to the lucrative clover seed crop in the first year of conversion and high organic wheat yield. The high organic wheat yield and low variable costs during conversion meant RCRC had the second highest strategy mean annual gross margin of £632 ha^{-1}.

Table 6. The annual gross margins (£ ha^{-1}) of the conversion strategies and of organic wheat, and the strategy mean annual gross margins, calculated with subsidies (AAP + OFS) and *without subsidies* (-AAP, -OFS).

Strategy	First Year Conversion		Second Year Conversion		First Organic Year (wheat)		Strategy Mean Annual GM	
RCRC	†374	*-78*	†362	*0*	1161	*884*	632	*269*
VEVR	†332	*-120*	†271	*-91*	828	*551*	477	*114*
CSRC	705	*398*	†362	*0*	1022	*745*	696	*362*
UWRC	312	*-140*	†362	*0*	975	*698*	550	*186*
WHBE	386	*-66*	433	*37*	755	*478*	525	*150*
OABE	436	*-16*	470	*74*	810	*533*	572	*197*
UWBP	312	*-140*	371	*9*	707	*430*	463	*100*

† Indicates crop is eligible as set-aside

The robustness of the gross margins was analysed by conducting sensitivity about conversion crop yields (± 1 s.d.) and conventional prices (± 20% and 50%). Under this sensitivity analysis the ranking of strategies according to gross margin changed slightly: CSRC and RCRC mean annual gross margins remained highest and second highest respectively, under all conditions; UWRC outperformed OABE with a decrease in yields by 1 s.d. or with a 50% fall in prices; WHBE mean annual gross margin was greater than UWRC with a 50% increase in prices; and UWBP mean annual gross margin was greater than that of VEVR under all yield and price increases, but lower under all yield and price decreases.

A sensitivity analysis was also undertaken about the first organic wheat yields (± 1 s.d.) and organic prices (± 20% and 50%). Mean annual gross margins of all strategies change, and the ranking of strategies by mean annual gross margin is affected to a greater extent than through sensitivity analysis of the conversion crops. The CSRC strategy mean annual gross margin again remains the highest under all sensitivity conditions, however, the large variation in organic wheat yield associated with OABE strategy means that with yield increases of 1 s.d. its mean annual gross margin becomes second highest, above RCRC, the only occasion studied when this occurs.

Regarding changes in support payments, removal of AAPs would have more of an impact on the organic conversion than the removal of the OFS. In the absence of all subsidies CSRC and RCRC strategies still generate modest mean annual gross margins of £362 ha^{-1} and £269 ha^{-1} respectively, due to high crop yields and low variable costs during conversion. The mean annual gross margins of the remaining strategies are under £200 ha^{-1}, and net margins are therefore unlikely to be above zero. Under the Organic Action Plan (DEFRA, 2002a), the government are to introduce an organic production subsidy, amounting to £30 ha^{-1} for five-year production contracts, to reward farmers for the benefits that organic farming methods are believed to provide to the wider public. For newly converted land this sum would boost the OFS subsidy of £50 ha^{-1} in the first organic year, and help offset any losses (relative to conventional production) incurred during the conversion period.

In summary the CSRC strategy provides the highest mean annual gross margin but is dependent upon securing a specialised seed production contract. Given current AAP and OFS payments, RCRC, providing the second highest gross margin is thus likely to remain an appropriate strategy choice for most farmers. In the absence of AAPs, RCRC will remain popular, not through the financial incentive of set-aside payments, but due to the enhanced yield of the first organic crop post conversion. OABE is also a potential conversion strategy if changes to organic conversion rules were made to allow such strategies to qualify for OFS payments.

Farm level modelling

The aim of the mixed integer, linear programming model was to simulate the organic conversion of an arable farm, using cropping strategies and gross margin data from the field experiment. The model has been successful in this endeavour, and six model "scenarios" have been examined. The scenarios were chosen to allow the model to select appropriate conversion strategies given the presence and absence of the farm securing a contract to supply clover seed and the presence and absence of current AAP and OFS payments under two farm sizes as detailed in Table 7.

Table 7. The six scenarios examined in the model

Scenario	**CSRC strategy**	**Subsidies**	**Farm size (ha)**
1	Present	With	250
2	Absent	With	250
3	Absent	With	500
4	Present	Without	250
5	Absent	Without	250
6	Absent	Without	500

In each year of the model, for four consecutive years, a quarter of the farm was entered into organic conversion until, in year 6, the whole rotation became fully organic. Given current prices and experimental yields conversion was more profitable than conventional production and any investments incurred during conversion were offset within the six-year period. Thus, on this basis, conversion can be recommended. Land was generally allocated to strategies with the highest average annual gross margin. This was the clover seed strategy (CSRC) under the assumption that a contract to supply clover seed could be secured, or two years' red clover-ryegrass green manure (RCRC) in the absence of a clover seed contract. Both of these clover strategies are generally labour demanding in the busy autumn period. The timing of labour demands is an important consideration at the farm level. When the demand for labour from these strategies is greater than the potential supply (covering both normal and overtime hours), two appropriate choices can be made: the farm can choose to employ another worker, or select another conversion strategy that is less demanding of labour in the busy autumn period. Faced with this choice the most profitable approach is to use more than one conversion strategy in each year and spread the labour demands facing the farm between autumn and spring. Thus when labour demands are greater than the amount that can be supplied by the farm, rather than choosing to employ another worker an appropriate strategy choice is spring oats followed by winter beans (OABE), or undersown spring wheat followed by a red clover green manure (UWRC). In this case the farm would generally use a combination of a clover seed strategy (CSRC, RCRC) and OABE or UWRC to convert parcels of land in each year. Thus, for farms where constraints on labour in the busy autumn period are not too great the clover strategies are an appropriate conversion cropping choice. For farms that are more restricted in their labour availability a combination of strategies as outlined above may prove more attractive. To account for variability and thus risk during the conversion period, sensitivity analysis was conducted to explore the impact of strategy choice when yields and prices vary. This analysis indicates that, in general, the strategy choices as outlined above remain the most appropriate under the variations in yield that were measured from the field experiment, and also given variations in both conventional and organic crop prices. In general, the level of investment needed during the conversion period, relative to conventional production, was low and should not deter growers from conversion. On a 250 ha farm, organic prices could fall by 26% (with subsidies) or 34% (without subsidies) before organic and conventional production were equally profitable. In the absence of all subsidies neither conventional nor organic farm net margins were above zero, however, conversion became profitable if all organic prices increased by 20%.

This study provides information about the processes occurring in the soil and crops during and after the organic conversion period, and shows that the profitability of the farm business during a staggered conversion can be improved with choice of conversion strategy. Under each of the six scenarios examined two years' red clover (RCRC) was the most appropriate conversion strategy for a risk-averse grower, while spring oats followed by winter beans (OABE) may be a useful strategy when labour is restrictive and a stable cash flow is important; however current regulations mean that OABE may not qualify for the organic payments that have been assumed in this work. Red clover seed has the potential to be a valuable crop for the conversion period but is considered medium risk and is dependent on securing a seed production contract. Greater opportunities for red clover seed production in the UK would increase the appeal of this crop to growers considering conversion. The evidence presented herein suggests that organic regulations stipulating fertility-building cropping in the first year of conversion could be relaxed without compromising the agronomic sustainability of the rotation. The development of a market for 'in-conversion' produce would also help ease growers' concerns about farm income during the conversion period.

When averaged over the whole rotation organic production compares well to conventional in GM terms due to high price premiums and low variable costs. However, these average figures mask the greater yield variability and risk of crop failure in organic systems. Growers wishing to convert to stockless organic production must bear in mind their specific farm circumstances including enterprise mix, farm business situation, and strength and availability of local organic markets.

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APPENDIX 1

The effect of conversion strategy on the yield of the first organic crop

Introduction

Since the introduction of new Organic Farming Scheme (OFS) in 1999 there has been an overall increase in the total area of organic and in-conversion land in England, from 150,000 ha in April 2000 to 246,688 ha in April 2002, the latter approximately 2.5% of all English farmland (DEFRA, 2002). However, over 80% of this organically managed land is grassland, associated with mixed farming systems. Although 42% of all conventionally managed land in England is in arable production, the equivalent figure for organic land is just 13%. Moreover, only 20% of the UK demand for organic cereals for human consumption is currently supplied by domestic production (DEFRA, 2002).

Most organic production occurs in central and southern England, which includes somewhat marginal cereal land, and although cereals are grown, grass and fodder are the main organic enterprises (Ilbery, Holloway and Arber, 1999). In contrast, the majority of conventional arable production occurs in the eastern counties of England, in stockless systems. There are a number of possible reasons dissuading stockless farmers from conversion, including low and variable crop yields and risk of crop failure, the limited options for weed, pest and disease control, and the difficulties of nutrient management without animal manures. But there is evidence from two long-term experiments in the UK that stockless production is viable, in agronomic terms (Cormack, 1999; Bulson, Welsh, Stopes and Woodward, 1996). With up to 130% price premiums available for organic combinable cereal and grain legumes compared to conventionally produced food, organic production presents a promising opportunity for stockless growers. However, a final barrier to conversion is the conversion period itself (O'Riordan and Cobb, 2001; Taylor, Watson, Stockdale, McKinlay, Younie and Cranstoun, 2001; Dabbert and Madden, 1986). This is usually a two-year period, commencing from the last application of a prohibited substance (e.g. pesticides), and is a legal requirement of organic certification. Current organic regulations stipulate that cropping during this two-year period must maintain or increase soil fertility (UKROFS, 2001). Indeed, the fertility of most soils must be improved in order to support the subsequent rotation. Amongst the aims of a 'fertility-building' conversion are therefore: the provision of nutrients (especially nitrogen) to support subsequent cropping; to improve the physical, biological and chemical attributes of soil that are associated with fertility; and to suppress weeds, pests and diseases, to provide a 'clean' seedbed.

In a stocked system the conversion period can be planned to coincide with grass-clover ley, and used for grazing, whereas in a stockless system a popular conversion strategy is a red clover (*Trifolium pratense* L.) -ryegrass (*Lolium spp.* L.) green manure (Lampkin, 1994b). The green manure is cut and mulched several times during the growing season to add nitrogen to the soil, and incorporated at the end of conversion. However, this means the land is effectively out of production for two years and substantial financial penalties may be incurred as a consequence. The green manure may be eligible for set-aside[2] subsidies, as well as OFS subsidies, but the future level and availability of such payments are uncertain.

Thus, most researchers agree that the conversion period is a time of reduced income on farms, an 'investment period', where losses are expected (O'Riordan and Cobb, 2001; Leake, 1996; Lampkin, 1994a). The potential for reducing financial losses during the period could be approached by either a) maximising the yield of the first fully organic crop after a fertility-building conversion, to off-set conversion losses, or b) using commercial cropping during the conversion to generate more income from the converting land, which may have an adverse impact on subsequent fully organic crops.

Organic winter wheat (*Triticum aestivum* L.) is currently the highest grossing organic cereal in the UK and accounts for approximately 40% of the land occupied by organic arable crops (DEFRA, 2002). It is likely to be the first crop grown after the organic conversion period, or after the fertility-building phase in the rotation (Lampkin, Measures and Padel, 2002), as it is nutrient demanding but also expected to offset the losses from the previous fertility-building phase. The average UK organic winter wheat yield is 4 t ha^{-1} (Lampkin *et al.*, 2002), compared to 8 t ha^{-1} for conventionally grown wheat (Nix, 2002). Research in conventional systems has revealed that nitrogen supply is a major determinant of wheat grain yield in non-droughted plants due to its effects on crop canopy, development and components of yield (e.g. Sylvester-Bradley, Stokes and Scott, 2001) and organic wheat is no different (Gooding, Davies, Thompson and Smith, 1993).

To determine the effect of conversion cropping strategy on the first organic winter wheat crop in a stockless farming system, an experiment was set up on land undergoing conversion. The aim of this paper is to report the main findings of this experiment.

[2] A derogation from DEFRA is required for set-aside land with over 5% legume content of sward.

Materials and Methods

Experimental Site and Design

The field experiment was carried out between 1999 and 2002 at Bunny Park Farm, Nottinghamshire, England (52°,52'N, 1°,07'W). The 30-year mean (1961-1990) annual rainfall at the nearest meteorological station (Sutton Bonington, Leicestershire) is 600 mm, mean annual air temperature is 9.3 °C. The soil texture on the experimental site fell into two broad categories of sand (blocks 1 and 2) and clay (blocks 3 and 4), and was in the Dunnington Heath series. The soil texture over all blocks and other soil properties are presented in Table 1.

Table 1. Soil properties at the beginning of the experiment. WHC (0.33 bar) = water holding capacity, OM = organic matter.

Block	Textural class	% silt	% sand	% clay	WHC % w/w	OM % w/w	pH
0 - 0.3 m depth							
1	sandy loam	13	72	15	14.1	1.6	7.5
2	sandy loam	13	69	18	13.9	2	7.3
3	sandy clay loam	18	58	24	16.9	2	7.3
4	sandy clay	20	48	32	20.8	2.2	7.6
0.3 - 0.6 m depth							
1	sandy loam	12	73	15	12.7	1	7.3
2	sandy clay loam	17	57	26	15	1.2	7.1
3	clay loam	20	45	35	20.7	1.2	7.5
4	Clay	23	38	39	25.5	1.3	7.8
0.6 - 0.9 m depth							
1	sandy loam	8	74	18	11.4	0.7	7.3
2	sandy clay loam	18	52	30	16.9	0.7	7.5
3	Clay	31	21	48	26.9	0.9	7.8
4	Clay	25	34	41	29.8	1.3	7.9

The conventional rotation prior to conversion was first winter wheat, second winter wheat, winter barley (*Hordeum vulgare*), oilseed rape (*Brassica napus subsp. oleifera* L.) / set-aside. The site entered organic conversion in August 1999, following the harvest of the second conventional winter wheat crop, and the site was registered with Organic Farmers and Growers Ltd. (Shrewsbury, UK). A red clover (cv. Rajah) -ryegrass green manure was sown across the entire experimental site on 5 September 1999.

The experimental plots (each 12.5 x 30.0 m) were arranged in a randomised block design comprising seven treatments and four replicates. Seven two-year conversion strategies were studied on the experimental site (Table 2). The four-letter abbreviations used in Table 2 will be used from this point forward to denote each conversion strategy. Two strategies were based on the previously established clover-ryegrass green manure (RCRC and CSRC in Table 2), and five other strategies were established in March 2000. Winter wheat (cv. Hereward) was grown across the entire experimental area in the third year, as the first fully organic crop.

Table 2. The conversion strategies were two-year cropping sequences, all followed by wheat in the third year. † A cut and mulched green manure; u/s = undersown with red clover.

Strategy	First Year Conversion		Second Year Conversion
RCRC	† red clover-ryegrass	-	† red clover-ryegrass
VEVR	† hairy vetch	-	† hairy vetch-rye (cv. Motto)
CSRC	red clover (grown for seed crop) -ryegrass	-	† red clover-ryegrass
UWRC	u/s spring wheat (cv. Paragon)	-	† red clover
WHBE	Spring wheat (cv. Paragon)	-	winter beans (cv. Clipper)
OABE	spring oats (cv. Solva)	-	winter beans (cv. Clipper)
UWBP	u/s spring wheat (cv. Paragon)	-	spring pea (cv. Agadir) - spring barley (cv. Static)

Crop Management

The site was managed according to organic regulations and no amendments of any kind were imported on to the site. The only inputs to the plots were plant biomass derived from the plots themselves. All plots were heavy disc cultivated on 17 September 2001, at the end of the conversion period. Weeds were allowed to germinate on the plots before being destroyed by ploughing on 1 November. Organic wheat seed was drilled using a power harrow-drill combination on 6 November at 470 seeds m^{-2}. Comb-harrowing of the plots on sandy soil (blocks 1 and 2) was carried out on 8 March and 16 April 2002.

Plant Growth Analysis

Wheat establishment was determined on 25 January 2002, by counting plants in ten 0.5 x 0.5 m wire quadrats which were placed in pre-determined randomised locations in each plot. Samples of above-ground biomass were taken for growth analysis from all plots on 15 April at GS 31 (15 April), GS39 (25 May), GS61 (17 June) and pre-harvest on 13 August. At each sampling date, five 0.5 x 0.5 m wire quadrats (1.2 x 0.6 m quadrats for pre-harvest sampling) were placed in pre-determined randomised locations in each plot. Crop species and weed species were removed at ground level, separated by hand, and then the quadrat samples bulked for each plot. Shoot number was counted at GS31 and GS61, and determined from ear number at harvest. The biomass of fresh and oven-dried material was taken. All plant samples were ground to a fine powder (Clyclotec, 1093 Sample Mill) and samples were sent through an elemental analyser (Fison NA2000) to determine percentage total nitrogen content.

Harvest Yield and Quality

The grain was harvested from all plots on 22 August with a plot combine harvester (Sampo Rosenlew 2010). The minimum area used to determine combine yield was $50m^2$. Grain yield was also estimated from the pre-harvest quadrat samples. Ears were counted to determine ear density, then threshed and cleaned to separate the chaff, grain and broken grains. Grains per ear were recorded and thousand grain weights (TGW) calculated for clean grain using a seed counter (Contador, Pfeuffer, Germany). To derive grain protein content from nitrogen content, percentage values of nitrogen content were multiplied by 5.83.

Soil Sampling

Soil cores were removed from pre-determined randomised locations in the experimental plots using an auger on 21 February 2002. Six cores per plot were removed at 0-0.3, 0.3-0.6 and 0.6-0.9 m depths. Samples from the same depth in the same plot were mixed together to create an average sample for the plot (bulking). Soil structure was assessed in March 2002 by inserting a sharp spade vertically into the soil to its full depth, levering out the soil and making a visual examination. Structure is scored on a scale of 1-10 where 1 = very big clods, smooth dense crack faces, reducing conditions, roots only in cracks; 10 = entirely porous crumbs.

Results

As noted above a number of factors are hypothesised to affect the yield of the first organic wheat crop post conversion. This section provides the results of the experiment by detailing grain yield and quality, harvest index and components of yield according to conversion strategy. The factors that lead to differences in performance of the first organic wheat crop are then presented: organic wheat establishment, shoot production and survival, nitrogen availability, and weed competition.

Grain Yield and Quality

Conversion strategy had a significant effect on combined grain yield of organic wheat (Table 3; *P*=0.002). Wheat following RCRC, CSRC and UWRC strategies had the highest yields, greater than the UK average organic wheat yield of 4 t ha^{-1} (Lampkin *et al.*, 2002). The remaining strategies produced yields below this average. All yields were lower than the typical conventional yield of 8 t ha^{-1} (Nix, 2002). There was a tendency for greater yields on sandy soil than clay soil (*P*=0.064), and there was a significant interaction between soil texture and conversion strategy (*P*=0.024), such that wheat following WHBE and OABE performed relatively worse on the clay soil than sandy soil, compared to the other strategies.

Grain yield estimates from hand-harvested quadrat samples are included for completeness (Table 3), as they were used in the determination of harvest index and in the components of yield analysis. These yields differ from the combine-harvested yields due to factors such as greater loss of grain during combining, the retention of smaller grain during quadrat harvesting, and a smaller area sampled during quadrat sampling, which may increase variability of data.

The quality specifications for organic milling wheat are similar to conventional wheat, with over 13% grain protein content required for premium prices (NABIM, 2002). Conventionally-grown Hereward typically reaches this target (HGCA, 2002a), however, experimental grain protein contents averaged just 10.9%, with no significant effect of conversion strategy (*P*=0.790).

Harvest Index

Harvest index of wheat following WHBE, OABE and UWBP was significantly lower than remaining strategies (Table 3; *P*=0.002). These low values could be the result of either a decrease in grain yield, or an increase in overall crop dry weight, but are likely to be caused by low grain yields in this case. Less assimilate might be partitioned to the grain as a result of lower photosynthesis during the developmental stages, i.e., during the determination of grain number between GS31 and GS61 and the determination of grain size in the weeks following GS61. Reduced photosynthesis may have been caused by an early powdery mildew (*Erysiphe sp.*) infection, which was first observed on 8 January 2002.

Components of Yield

Ear density was highest in wheat following strategies with clover in the second year of conversion (Table 3; *P*=0.036), while ear density tended to be greater on sandy soil than clay soil (*P*=0.085). Ear density is a product of plant population and tillering, but was related to plant population alone in this case (Figure 1; $P<0.001$). As noted above, data on shoot production and survival were variable, in that some plants were better able to compensate for low population through tillering than others, however this was not related to levels of SMN in spring.

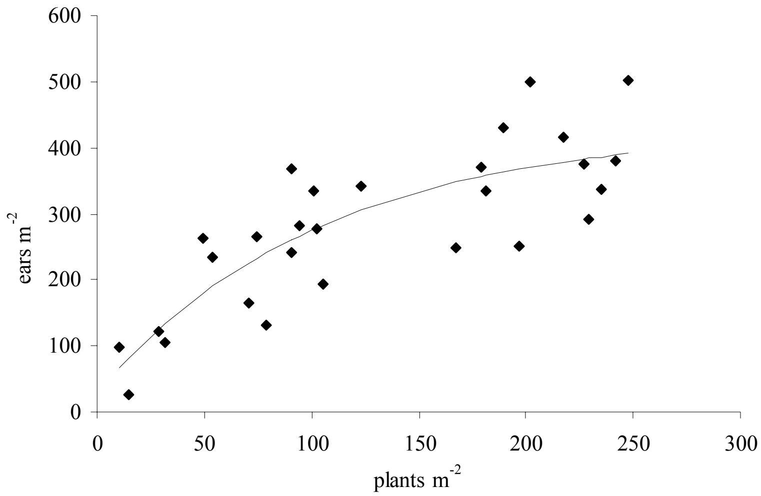

Figure 1. The exponential relationship between ear density and plant population. (Ears m^{-2} = $427.4 – 398.2*(0.99041^{\text{plant population}})$; $R^2 = 0.68$).

There were no effects of conversion strategy on number of grains per ear (Table 4; $P=0.672$), although there were more grains per ear on clay soil than sandy soil ($P=0.022$), probably a compensatory mechanism for low ear density in these plots. Wheat following WHBE had a particularly low TGW, but values were similar amongst the other strategies (Table 4; $P=0.038$). There was a significant interaction between conversion strategy and soil texture, whereby wheat following WHBE, OABE and VEVR had higher TGW on sandy soil, while wheat following RCRC, CSRC and UWRC strategies had higher TGW on clay soil (Table 4; $P=0.003$).

Variation in grain yield (85% DM; quadrat samples) could be accounted for by ear density and thousand grain weight, according to the following relationship:

$$\text{Grain yield} = \underset{(P<0.001)}{0.0138*\text{ears m}^{-2}} + \underset{(P=0.002)}{0.096*\text{TGW}} – 3.66$$

($R^2 = 0.94$; $P < 0.001$)

Adding grains per ear to the model did not improve this relationship.

Table 3. Combine-harvested and quadrat sampled grain yield estimates (t ha^{-1}) (85% DM) of organic wheat, and harvest index (%; 100% DM; based on quadrat samples), as affected by conversion strategy and soil texture.

	Combine-harvest yield estimate			Quadrat sample yield estimate			Harvest index		
Conversion strategy	Sand	Clay	**Mean**	Sand	Clay	**Mean**	Sand	Clay	**Mean**
RCRC	6.07	4.49	**5.28**	6.54	4.48	**5.51**	45.9	47.0	**46.5**
VEVR	4.78	2.18	**3.48**	6.25	3.61	**4.94**	48.1	46.0	**47.1**
CSRC	5.14	3.92	**4.53**	6.74	5.98	**6.36**	48.0	45.9	**47.0**
UWRC	4.99	3.55	**4.27**	7.37	4.49	**5.93**	48.2	47.5	**47.9**
WHBE	5.11	1.05	**3.08**	4.95	1.37	**3.16**	44.8	42.0	**43.4**
OABE	5.64	1.12	**3.38**	5.70	2.48	**4.09**	43.3	41.5	**42.4**
UWBP	3.90	1.74	**2.82**	5.87	3.37	**4.62**	45.7	41.7	**43.7**
Mean	**5.09**	**2.58**		**6.21**	**3.68**		**46.3**	**44.5**	
	P value	SED	df	*P* value	SED	df	*P* value	SED	df
Conversion strategy	0.002	0.475	12	0.020	0.781	12	0.002	1.13	12
Soil texture	0.064	0.665	2	0.145	1.080	2	0.183	0.89	2
Conversion strategy *soil texture	0.024	0.911	6.2	0.661	1.488	6.3	0.456	1.72	12.5

Table 4. The effects of conversion strategy and soil texture on organic wheat ear density (ears m^{-2}), grains per ear and thousand grain weight (g; 85% DM).

	Ear density			Grains per ear			Thousand grain weight		
Conversion strategy	Sand	Clay	**Mean**	Sand	Clay	**Mean**	Sand	Clay	**Mean**
RCRC	438	218	**328**	34.0	43.1	**39.5**	48.5	50.8	**49.7**
VEVR	311	193	**252**	40.2	45.3	**43.8**	53.3	46.4	**49.8**
CSRC	406	308	**357**	38.1	38.2	**38.1**	50.0	51.9	**50.9**
UWRC	420	215	**318**	38.1	46.7	**42.4**	50.1	51.0	**50.6**
WHBE	292	79	**186**	38.4	41.4	**40.9**	52.0	37.5	**44.7**
OABE	354	166	**260**	32.9	41.8	**37.4**	53.7	47.0	**50.4**
UWBP	352	191	**272**	38.4	33.5	**36.9**	49.7	46.7	**48.2**
Mean	**368**	**196**		**37.1**	**41.4**		**51.0**	**47.3**	
	P value	SED	df	*P* value	SED	df	*P* value	SED	df
Conversion strategy	0.036	44.4	12	0.672	4.38	12	0.038	1.69	12
Soil texture	0.085	53.7	2	0.022	0.64	2	0.250	2.30	2
Conversion strategy *soil texture	0.732	79.2	7.7	0.633	5.77	12.3	0.003	3.19	6.5

Organic Wheat Establishment

Wheat establishment was generally low (Table 5): with a seed rate of 470 seeds m^{-2} even the highest plant population of 237 plants m^{-2} (following RCRC on sandy soil) represents just 50% establishment, while the experimental average establishment was 28%. Variation in establishment could not be directly related to conversion strategy (P=0.170), but establishment was three times better on sandy soils than clay soils (P=0.030).

While there were no significant effects of cropping on soil structure at the 5% level (Table 6; P=0.062), soil structure, together with soil texture, accounted for 89% of the variation in plant establishment (Figure 2). That is, greater establishment was associated with a high soil structure score, and a low value for soil texture. Soil texture was entered into the regression model as 0 for sandy soil, and 1 for clay soil, but the numbers cannot be interpreted as a continuous variable in the sense that a 0.5 soil texture is in no way 'equidistant' between sandy and clay soil.

Table 5. The effect of conversion strategy and soil texture on organic wheat plant populations (plants m^{-2}).

Conversion strategy	Sand	Clay	**Mean**
RCRC	237.4	98.0	**167.7**
VEVR	187.8	38.8	**113.3**
CSRC	215.8	97.8	**156.8**
UWRC	162.4	72.6	**117.5**
WHBE	174.6	46.6	**110.6**
OABE	223.4	32.0	**127.7**
UWBP	162.6	67.2	**114.9**
Mean	**194.9**	**65.0**	

	P value	SED	df
Conversion strategy	0.170	23.91	12
Soil texture	0.030	23.25	2
Conversion strategy *soil texture	0.443	38.99	10.2

Table 6. Soil structure scores as affected by conversion strategy and soil texture. Structure is scored on a scale of 1-10 where 1 = very big clods, smooth dense crack faces, reducing conditions, roots only in cracks; 10 = entirely porous crumbs.

Conversion strategy	Sand	Clay	**Mean**
RCRC	7.29	6.21	**6.75**
VEVR	6.50	5.50	**6.00**
CSRC	6.71	6.21	**6.46**
UWRC	6.29	5.93	**6.11**
WHBE	6.50	5.00	**5.75**
OABE	6.57	5.00	**5.79**
UWBP	6.00	5.57	**5.79**
Mean	**6.55**	**5.63**	

	P value	SED	df
Conversion strategy	0.062	0.326	12
Soil texture	0.074	0.265	2
Conversion strategy *soil texture	0.371	0.502	12.2

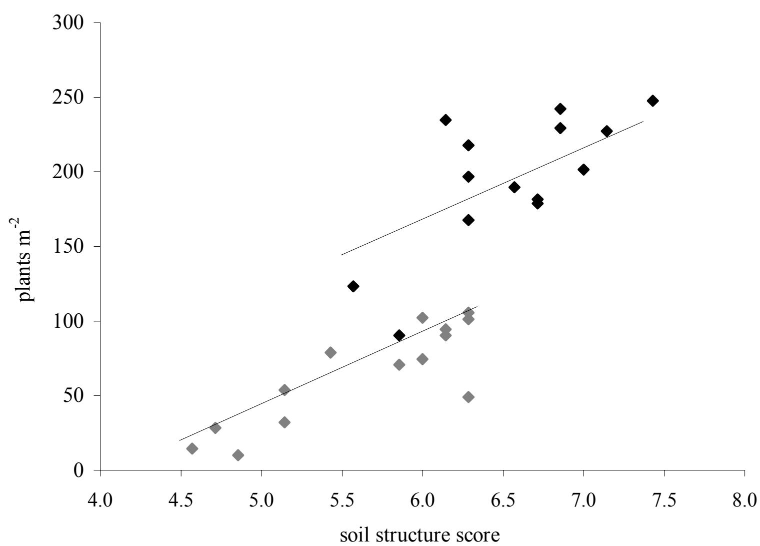

Figure 2. The relationship between soil structure, soil texture and establishment. Sand (◆), clay (◆). Curves fitted: Establishment = 52.42*soil structure score - 82.0*soil texture -148.6 (R^2 = 0.89; $P < 0.001$).

Shoot Production and Survival

At GS31 there was no effect of plant population on tillering, with an average of 3.0 shoots per plant (i.e., two shoots plus main stem). This is surprising, as it has previously been shown that more tillers per plant are produced at low populations (Whaley, Sparkes, Foulkes, Spink, Semere and Scott, 2000). At harvest there was an average 2.8 shoots per plant, implying minimal shoot mortality. There was, however, a considerable amount of variation associated with these data, especially at low plant populations. Previous work in conventional winter wheat demonstrated that shoots continued to be produced beyond GS31 in low populations (30 plants m^{-2}), and up to almost 100 days longer than at higher populations (218 plants m^{-2}) (Whaley *et al.*, 2000). In the present study shoot production and shoot mortality may have extended beyond GS31 and GS61 respectively in some populations, but not in others, leading to an inaccurate assessment of maximum and final number of shoots per plant at GS 31 and 61 respectively.

Nitrogen availability

In the first year of conversion RCRC and CSRC residues added to the soil following mulching or harvesting contained the most nitrogen, and, contrary to expectation, although some nitrogen was removed in the harvest of clover seed, there was no significant difference in nitrogen input between the two strategies (Table 7; P=0.001). In the second year of conversion RCRC, CSRC and UWRC contained similar amounts of nitrogen in residues.

In the organic wheat crop in February 2002 there was more soil mineral nitrogen (SMN) in soils following RCRC, CSRC and UWRC, than WHBE and UWBP conversion strategies (Table 8; P=0.022), due to greater addition of nitrogen in residues during the conversion. In February 2002 sandy soils contained double the SMN of clay soils (Table 8; P=0.020), despite no difference in the amount of nitrogen added via plant residues to sandy and clay soils in 2000 or 2001 (Table 7; P=0.132; P=0.150 respectively). It is likely that warmer temperatures in sandy soils (as a result of lower water retention than clay soils) encouraged faster rates of mineralisation (Rasiah, 1999). Despite the large difference in February SMN, multiple regression analysis showed that, once soil structure and texture were accounted for, SMN did not help to explain the variation in ear number (P=0.244).

Table 7. The nitrogen content (kg N ha^{-1}) of crop and weed residues added to the conversion strategies during the first and second years of conversion, and in total, on two soil textures.

Conversion strategy	First Year Conversion			Second Year Conversion			
	Sand	**Clay**	**Mean**	**Sand**	**Clay**	**Mean**	**Total**
RCRC	257.1	219.2	**238.2**	330.1	327.2	**328.6**	**566.8**
VEVR	181.8	149.3	**165.6**	290.2	127.2	**208.7**	**374.3**
CSRC	223.7	210.5	**217.1**	273.2	249.6	**261.4**	**478.5**
UWRC	109.4	104.4	**106.9**	285.0	321.5	**303.3**	**410.2**
WHBE	42.8	21.9	**32.3**	105.7	90.7	**98.2**	**130.5**
OABE	28.0	25.5	**26.8**	112.4	99.9	**106.1**	**132.9**
UWBP	103.6	99.7	**101.6**	39.5	57.0	**48.3**	**149.9**
Mean	**135.2**	**118.6**		**205.1**	**181.9**		

	2000			2001		
	P value	SED	df	*P* value	SED	df
Conversion strategy	< 0.001	17.66	12	< 0.001	30.91	12
Soil texture	0.132	6.70	2	0.150	10.21	2
Conversion strategy *soil texture	0.909	24.07	13.5	0.114	41.74	13.3

Table 8. SMN (kg ha^{-1}; 0-0.9 m) in February 2002, as affected by conversion strategy and soil texture.

Conversion strategy	February 2002		
	Sand	Clay	**Mean**
RCRC	120.3	50.5	**85.4**
VEVR	97.5	38.0	**67.7**
CSRC	143.9	53.2	**98.6**
UWRC	114.4	67.1	**90.7**
WHBE	80.2	40.2	**60.2**
OABE	86.2	52.0	**68.6**
UWBP	63.6	49.0	**56.3**
Mean	**100.9**	**49.8**	

	February 2002		
	P value	SED	df
Conversion strategy	0.022	11.64	12
Soil texture	0.020	7.27	2
Conversion strategy *soil texture	0.105	16.88	13.8

Weed Competition

In all organic wheat crops weed DM was low during the early part of the growing season but increased as the crop senesced at harvest in August 2002, taking advantage of greater resource availability (Figure 3). Despite large differences there were no significant effects of conversion strategy on weed DM production at any growth stage due to large variability. This variability was probably a result of small numbers of large individual weeds, such as docks, which occurred infrequently but had a large impact on biomass. Eight species represented over 80% of all weed DM production: annual meadow grass (*Poa annua*), bugloss (*Anchusa arvensis)*, creeping thistle (*Cirsium arvense*), dock (*Rumex* spp.), fat hen (*Chenopodium album*), ivy-leaved speedwell (*Veronica hederifolia)* orache (*Atriplex patula)* and scentless mayweed (*Tripleurospermum inodoratum*). Adding a weed DM term at any growth stage did not improve the relationships describing yield formation, i.e. grain yield and weed DM were not directly related once plant population was taken into account. Thus, weed abundance had either no impact on wheat yield, or the overriding effects of plant population masked any such impact.

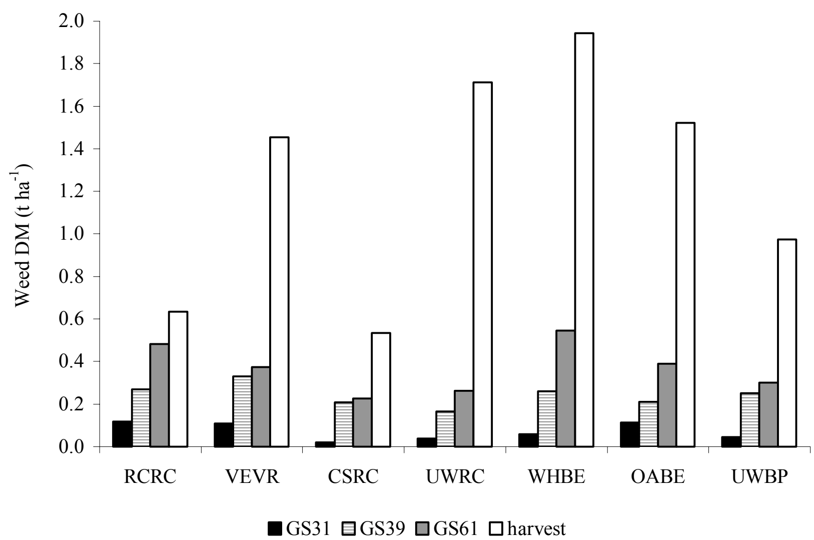

Figure 3. Weed dry matter (DM) production in the organic wheat crop. (SED at GS31 = 0.064, GS39 = 0.201, GS61 = 0.182, harvest = 0.726; 12 df).

It is surprising that weed density was not affected by previous cropping, as there were significant differences in weed density between strategies during the conversion period. In the second year of conversion (2000-2001), weed density in RCRC, CSRC and UWRC was low throughout the whole season (Figure 4). By the end of the season the barley-pea intercrop (UWBP strategy) contained the most weeds, amounting to 29% of total above-ground DM production. Weed density was higher in the barley-pea intercrop than the bean crops in the second year of conversion (P=0.002). This was probably due to a better soil tilth under the barley-pea crop compared to the bean crops, which were simply ploughed in and the soil not rolled due to adverse weather and soil conditions.

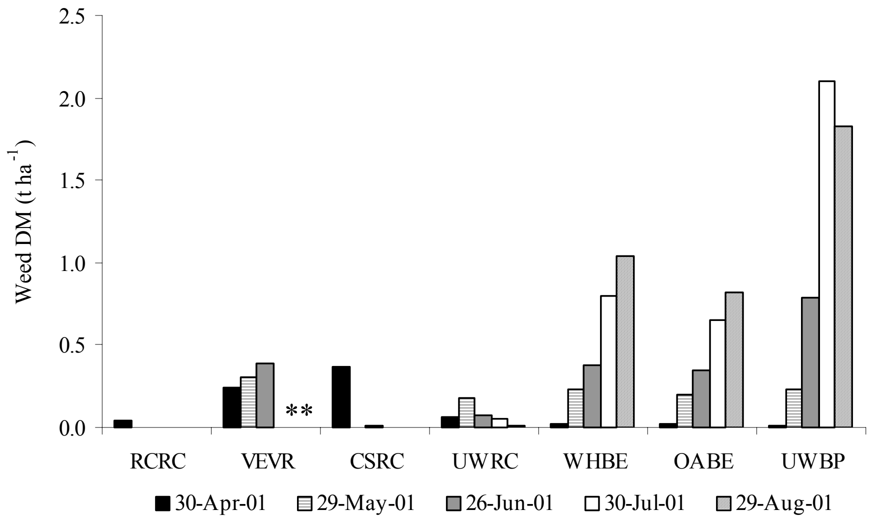

Figure 4. The effect of conversion strategy on weed dry matter (DM) production in the second year of conversion. SED (30-Apr-01) = 0.093, 12 df; SED (29-May-01) = 0.094, 12 df; SED (26-Jun-01) = 0.115, 12 df; SED (30-Jul-01) = 0.274, 10 df; SED (29-Aug-01) = 0.354, 10 df. ** Crop destroyed 2 July 2001.

Discussion

Organic winter wheat yields were greatest after strategies containing a long red clover green manure phase, but this was not related to levels of soil mineral nitrogen. Rather, soil structure interacted with soil texture to influence plant establishment, which was the main determinant of yield. Conversion cropping could have influenced soil structure through a variety of mechanisms, which are by no means mutually exclusive: rooting longevity, frequency of cultivation, worm activity and magnitude and quality of residue inputs (Anges & Caron, 1998). Previous work has also attributed yield responses of winter wheat following green manure incorporation to differences in soil structure. (Abdallahi and N'Dayegamiye, 2000)

Soil texture also influenced yield, but contrary to expectation, yields were better on sandy than clay soils. It had been hypothesised that the clay soil would support greater yields by virtue of increased moisture and nutrient retention. However, the free draining, more easily worked sandy soil proved to be more suitable for crop establishment.

The average establishment of 28% was low compared to the benchmark of 70% for conventional crops (Sylvester-Bradley, Scott and Clare, 1997). The main reason for the poor establishment is probably the late sowing on 6 November. Delaying drilling until mid-November reduced establishment in conventional wheat to as low as 42% (Spink, Semere, Sparkes, Whaley, Foulkes, Clare and Scott, 2000). Slug grazing reduced establishment further. Field observations revealed that there was severe slug grazing of shoots on the clay soil in particular. Wet weather conditions at drilling precluded the use of rolls to consolidate the soil, which would have created a less hospitable environment for slugs. To an extent the sandy soil was naturally better consolidated as the smaller soil aggregates pack together more closely, while the more 'cloddy' nature of the clay soil favoured slugs, which shelter beneath the soil surface. In addition, the clay soil was more moisture-retentive than the sandy soil, which would also favour slugs. Differential slug grazing may have caused wheat following WHBE and OABE to yield less on clay soil than sandy soil, compared to the other strategies. The slower decomposition of crop residues from bean residues in WHBE and OABE strategies, may have favoured slugs by providing a food source throughout the winter and increasing populations. In addition the seedbed, which was open, with large aggregates on the surface, was probably a more favourable environment for slugs.

Overall, ear density was low compared to the recommended target for conventional wheat of 500-600 ears m^{-2} (Sylvester-Bradley *et al.*, 1997). Such low ear densities may not be unusual for an organic crop; an ear density of 220 ears m^{-2}, from a seed rate of 500 seeds m^{-2}, has been recorded in organically grown Hereward (Thompson, Gooding and Davies, 1993). Some crops were better able to use tillering to compensate for low population than others. The capacity for conventional crops to compensate for low populations through tillering declines as sowing date is delayed (Spink *et al.*, 2000). Organic crops are sown later to allow for stale seedbeds, as a weed control mechanism, but a higher seed rate is used to offset the potential for poor establishment and pest and disease damage, against which the organic farmer has little other defence. In conventional production fertiliser nitrogen is used to make up for poor establishment by encouraging greater tillering. In regression analysis, addition of a February soil mineral nitrogen (SMN) term did not improve the relationship between shoots per plant and plant population, although the timing of nitrogen supply to crops may have varied depending on conversion strategy, and would have impacted on the ability of the crops to tiller. It is possible that the activity of slugs, grazing on tillers without causing plant death, may also have affected measured shoot population. In addition, variable field conditions are known to increase the variability of crop growth and development. Indeed, up to 50% of yield variation may be attributable to soil variation (Sylvester-Bradley, Lord, Sparkes, Scott, Wiltshire and Orson, 1999). A powdery mildew infection was first observed on the organic wheat on 8 January 2002. Early powdery mildew infection has been shown to reduce tiller survival, grain weight and grain number of winter wheat (Everts and Leath, 1992; Bowen, Everts and Leath, 1991). The disease could account for difficulties in linking shoots per plant to the relationship between plant population and ear density in the present study. Hereward is particularly susceptible to mildew, scoring 5/10 in recommended lists (HGCA, 2002b).

None of the organic wheat crops achieved the grain protein content necessary for bread quality premiums. This is not surprising as grain protein levels are often lower in organic systems (Starling and Richards, 1990), and indicates that the crops were nitrogen-limited. Similar results were reported by Thompson *et al.* (1993) who grew organic Hereward after one years' red clover-ryegrass green manure which achieved 10.0% protein content with a grain yield of 5.6 t ha^{-1}. A feed variety of wheat may be preferred, which would be expected to yield more than a bread-making variety, and still attract an organic price premium.

Wheat yields were not related to weed density once the effects of wheat population were taken into account. This conflicts with the overriding view of organic farmers, that weeds are a problem in over half the cereal crops grown (Taylor *et al.*, 2001). Evidence from experiments in organic systems, where yield increases of up to 86% have been achieved in a completely weed-free organic wheat crop, supports this view (Welsh, Bulson, Stopes, Froud-Williams and Murdoch, 1999). However, contrary evidence also exists. In the stockless rotation experiments of Bulson *et al.* (1996) wheat yields were significantly inversely related to weed dry matter, although whether weeds were a cause of reduced yields, or simply the symptom of a poorly competitive crop could not be determined, however the authors argued that the latter was the case. Bulson *et al.*'s assertion is also supported by a study on weeds as a yield-limiting factor in organic tomato production (Clark, Horwath, Shennan, Scow, Lantni and Ferris, 1999). At relatively high weed density there was no evidence to suggest that weeds were competing with the crop for nitrogen. In the present study, the capacity of the conversion crops to suppress weeds had no impact on weed density in the first organic wheat crop.

SMN in spring has been identified as an indicator of final grain yield in winter wheat that was managed conventionally but did not receive fertiliser nitrogen (Sylvester-Bradley *et al.*, 2001). This effect was primarily due to improved shoot survival with increases in SMN, leading to increases in canopy size and ear density. In the present study variation in February SMN could not account for any more variation in ear density, than could be described by plant population alone. Indeed, the overwhelming effects of plant population are likely to have obscured any effect of February SMN on tillering.

The values of annual accumulated nitrogen from a year's red clover green manure are largely in agreement with reported figures of 250-292 kg N ha^{-1} and 371 kg N ha^{-1} (Bulson *et al.*, 1996; Stopes *et al.*, 1996, respectively). A two-year red clover green manure has been reported to accumulate 660 kg N ha^{-1} (Cormack, 1999), and 741 kg N ha^{-1} (Stopes *et al.*, 1996); both values higher than those measured in the present study. These figures are, however, somewhat misleading, in that they do not account for the cycling of nitrogen within the plant-soil system, especially in systems containing leguminous plants, that can lead to nitrogen atoms being counted more than once, and thus an over-estimate of net nitrogen addition. A simpler 'system nitrogen' measure, summing the nitrogen content of plant and soil at the same point in time avoids this problem, although it does not account for potentially mineralisable nitrogen contained within organic residues in the soil. On the basis of this 'system nitrogen' measure, in the first year of conversion, there was no difference between VEVR in July 2000 and RCRC in September 2000 (Figure 5a). Undersowing wheat with clover (UWRC, UWBP) substantially increased system nitrogen compared to the wheat monocrop (WHBE) ($P<0.001$). At the end of the second year of conversion all the strategies, except UWBP, contained similar amounts of system nitrogen, prior to the removal of grain (Figure 5b). Interestingly, no more system nitrogen was measured after two years of red clover than after one year. This finding supports earlier work showing that, in terms of nitrogen accumulation, the length of the red clover green manure may be reduced without adverse effects on the subsequent crop (Stopes *et al.*, 1996).

In conclusion, conversion strategy significantly altered the grain yield of a subsequent organic winter wheat crop. Greatest yields occurred following red clover green manures, which provided improved soil structure in comparison to other strategies and this was attributed to infrequent cultivations and high quantity and quality of crop residue input. The effects of cropping strategy on yield were not directly related to weed suppression or SMN but to soil structure, which together with soil texture accounted for variations in establishment, the main determinant of yield. It was anticipated that wheat (and conversion crops) would perform better on a more retentive clay soil. However, the free-draining, more easily worked sandy soil proved to be more suitable for crop establishment.

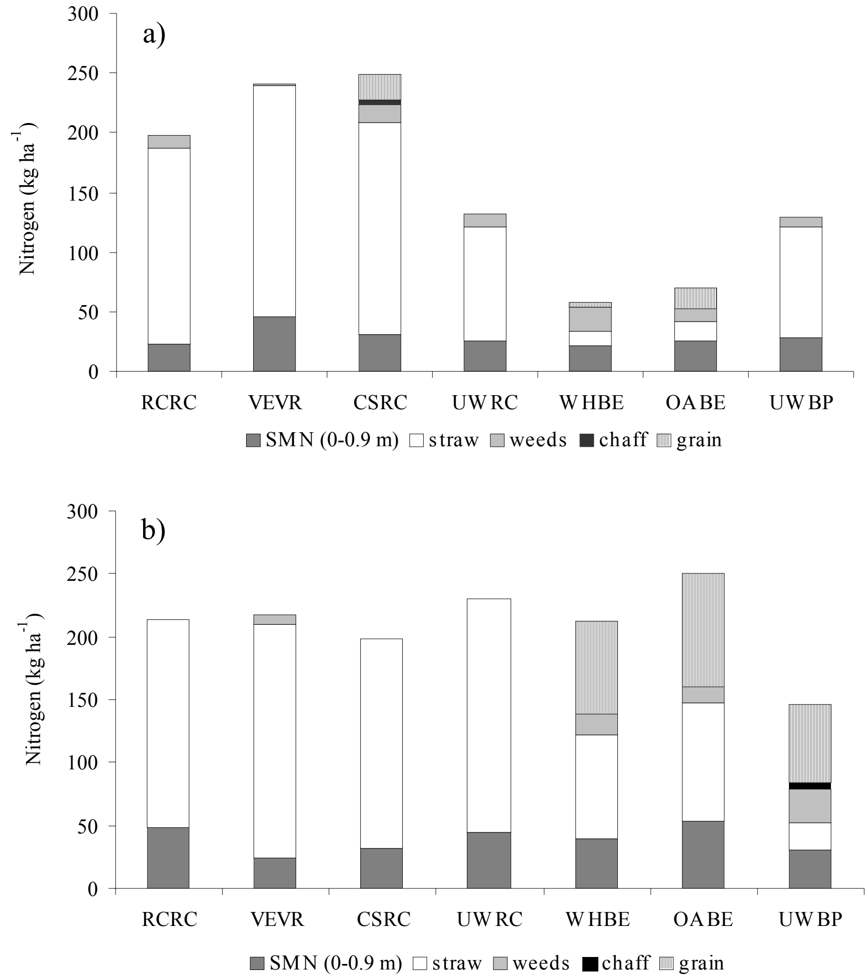

Figure 4. 'System nitrogen' in September for all conversion strategies except VEVR, which is compared at the destruction of the crop in July, in a) the first year of conversion (SED: 28.66, 18 df) and b) the second year of conversion (SED: 22.92, 18 df).

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Appendix 2

Economic analysis of conversion strategies for stockless organic production

Abstract

In response to the Curry Report the Government's Organic Action Plan aims to increase the area of organic production. However the main barrier to organic production is the conversion period. Typically a two-year red clover-ryegrass ley is used, attracting both AAP and OFS payments. Six alternative conversion strategies to red clover-ryegrass are tested in a replicated field experiment. Gross margin analysis in the presence and absence of AAP and OFS payments are presented. Sensitivity analysis of crop yields and prices indicates the robustness of the gross margin analysis. Where contracts to supply red clover seed can be obtained growing clover seed in year 1 of conversion followed by clover cut and mulched in year 2 provides the highest mean annual gross margin, measured over the two-year conversion period and the first organic wheat crop. In the absence of producing clover for seed the two-year red clover-ryegrass ley provides the highest mean annual gross margin. This holds in the absence of AAPs due the enhanced yield of the first organic wheat crop compared with more exploitative conversion strategies. Red clover-ryegrass ley is likely to remain a popular conversion strategy in both the presence and absence of AAPs. Other strategies that may be appropriate include oats followed by beans, however a change in policy on acceptable organic conversion crops would be required to enable this strategy to be considered.

Introduction

UK organic food sales in 2001/2002 reached £920 million, a rise of 15% on the previous year (Soil Association, 2002), making organic food approximately 4% of the total market (Holt, Tranter, Miele, Vestergaard, Nielson, Meehan and Sottomayor, 2002). Despite recent difficulties in some organic markets, particularly the milk sector, organic production may prove to be a valuable avenue for farmers wishing to become both more market-led and provide enhanced environmental outputs from their farm.

In the Strategy for Sustainable Farming and Food (DEFRA, 2002b) the government set out its vision for the future of farming in the UK. The government desires sustainable land management and high standards of environmental performance as part of a profitable farming industry. The Department for the Environment, Food and Rural Affairs (DEFRA) acknowledges that although organic production is not the only farming system capable of delivering these aims, it does have two main advantages: it operates according to a set of rules and regulations that are legislated for at the EU level, and it has achieved consumer recognition resulting in a price premium in the market (DEFRA, 2002a). Prices of organic cereals and combinable grain legumes in 2002 averaged approximately 130% more than conventional produce (Lampkin, Measures and Padel, 2002; Nix, 2002). The government currently supports organic farming through the Organic Farming Scheme (OFS), which provides £135 ha^{-1}, £125 ha^{-1}, £50 ha^{-1}, £20 ha^{-1}, £20 ha^{-1}, for the first five years from the start of conversion respectively. In response to the Policy Commission on the Future of Farming and Food (Curry, 2002) the government has published an Organic Action Plan (DEFRA, 2002a), a policy for organic food production to cover all parts of the food chain. Amongst the targets in the Organic Action Plan is the aim to increase the proportion of organic sales derived from UK production from the current levels of approximately 30%, to at least 70%, which is the equivalent level in the conventional market. Under the plan further support for organic farming is scheduled, initially in the form of an annual payment of £30 ha^{-1} once conversion is completed, based on five-year production contracts. Organic farming will also receive specifically targeted funds in the new structure of agri-environment schemes, to be developed over the period 2002 to 2004, as part of the England Rural Development Programme (ERDP). Through schemes such as this the ERDP aims to encourage an additional 45,000 ha of land (650 farmers) in England to enter organic conversion each year until 2006.

Meanwhile, the conventional sector is experiencing the lowest levels of profitability since the 1930s (DEFRA, 2002b). There are many reasons for this decline, including: the strength of sterling against the euro, thus reducing subsidy payments that UK farmers receive; weak negotiating power, as a result of the fragmented nature of the industry compared with upstream and downstream industries; and public food safety issues such as BSE and foot and mouth disease that lessen consumer confidence in the conventional food sector. In addition, the enlargement of the EU will bring greater competition from agriculture in the Eastern European countries, and in the 2001 round of the World Trade Organisation (WTO) talks in Doha, the government committed to further reductions in price supports, trade barriers and production subsidies. Indeed, the recent Mid Term Review (MTR) discussions, with attendant subsidy decoupling will, if implemented, build upon the WTO talks and provide farmers with an incentive to become more market-led in their production.

Thus, there is potentially a financial incentive for conventional farmers to convert to organic production. Since the introduction of new OFS money in 1999 there has been an overall increase in the total area of organic and in-conversion land in England, from 150,000 ha in April 2000 to 246,688 ha in April 2002, the latter approximately 2.5% of all English farmland (DEFRA, 2002a). However, over 80% of this organically managed land is grassland, associated with mixed farming systems. Although 42% of all conventionally managed land in England is in arable production, the equivalent organic figure is just 13%. Moreover, only 20% of the UK demand for organic cereals for human consumption is currently supplied by domestic production (DEFRA, 2002a). In light of the substantial price premiums available on organic produce, it is perhaps surprising that more organic arable production is not occurring.

Economics of Organic Conversion: Evidence from Literature

Most organic production occurs in central and southern England, which includes somewhat marginal cereal land, and although cereals are grown, grass and fodder are the main organic enterprises (Ilbery, Holloway and Arber, 1999). In contrast, the majority of conventional arable production occurs in the eastern counties of England, in stockless systems. There are a number of likely reasons dissuading farmers from conversion, including low and variable crop yields and risk of crop failure, the limited options for weed, pest and disease control, and the difficulties of nutrient management without animal manures (stockless organic rotations rely on symbiotic nitrogen fixation by leguminous plants to provide nitrogen for crop production, and on mineral sources of other essential nutrients, such as potassium and phosphorus) and uncertainty about the organic market. But recent evidence from two long-term experiments in the UK suggests that stockless production is viable, in both economic and agronomic terms (Cormack, 1999; Bulson, Welsh, Stopes and Woodward, 1996). Organic production therefore presents a promising opportunity for stockless growers. However, another barrier to conversion is the conversion period itself (Taylor, Watson, Stockdale, McKinlay, Younie and Cranstoun, 2001; O'Riordan and Cobb, 2001; Dabbert and Madden, 1986). This is usually a two-year period, commencing from the last application of a prohibited substance (e.g. pesticides), and is a legal requirement of organic certification. Current organic regulations stipulate that cropping during this two-year period must maintain or increase soil fertility (UKROFS, 2001). Indeed, the fertility of most soils must be improved in order to support the subsequent rotation. In order to achieve this a popular conversion strategy is a red clover (*Trifolium pratense* L.) -ryegrass (*Lolium spp.* L.) green manure (Lampkin, 1994b). The green manure is cut and mulched several times during the growing season and incorporated after two years. In a stocked system the conversion period can be planned to coincide with grass-clover ley, and used for grazing, but in a stockless system land is simply removed from production and substantial financial penalties may be incurred as a consequence. The green manure may be eligible for set-aside[3] subsidies, in addition to OFS subsidies, thus currently helping to finance any costs involved in conversion. However, if decoupled payments as proposed in the MTR are attached to a non-rotational set-aside policy then the option for using set-aside payments as a means of converting to organic production may not exist. In this case other conversion strategies that rely on in-conversion cropping may prove to be relatively more financially attractive than under the present policy environment.

Most researchers agree that the conversion period is a time of reduced income on farms, an 'investment period', where losses are expected (Lampkin, 1994a; Leake, 1996; O'Riordan and Cobb, 2001). However, despite this there has been little research conducted on farm profitability during the conversion period. Typically, the annual gross margins of converting land have been monitored during a staggered whole farm conversion (Higginbotham, Noble and Joice, 1996; O'Riordan and Cobb, 2001), and compared to non-conversion levels. Two studies have examined the impact of speed of conversion on profitability, including examining an all-in-one approach to conversion where the whole farm converts at the same time (Medcalf, Midmore, Lampkin and Padel, 1996; Ramsay, 1992). However, the impacts of alternative cropping during the organic conversion on either the subsequent rotation or farm profitability has not been considered in a stockless system in the UK.

The potential for minimising investment costs of conversion could be approached by either a) maximising the yield of the first fully organic crop after a fertility-building conversion, to off-set conversion losses, or by b) using commercial cropping during the conversion to generate more income from the converting land, and accept that this may have an adverse impact on subsequent fully organic crops. In-conversion crops may yield less than a conventionally

[3] A derogation from DEFRA is required for set-aside land with over 5% legume content of sward.

grown crop and will not qualify for an organic price premium. The choice between a) and b) or a compromise between these points is thus of central importance to those wishing to convert. This paper seeks to explore this issue explicitly through the analysis, at gross margin level, of seven conversion strategies, that are dependent upon experimental data from a UK field site. The next section reports the findings of experimental work by discussing the agronomic and economic performance of the conversion strategies and first organic crop post conversion. Incorporated within this section sensitivity analysis of the results provide indications of robustness of the conversion strategies to changes in both agronomic performance and market prices. The paper then considers overall profitability of organic versus conventional arable production before providing concluding comments.

Conversion Strategy Gross Margin Analysis

To explore fully the dynamics between generating revenue from commercial cropping during conversion and building soil fertility, a range of conversion cropping strategies (Table 1) that stretched the economic and agronomic limits of the conversion were tested in a replicated randomised block field experiment on land previously in the conventional rotation: winter wheat, second winter wheat, winter barley, oilseed rape (90%) / set-aside (10%). Factors considered in strategy design included the potential to increase soil nitrogen through nitrogen fixation; the potential to create revenue through the sale of crops and the resultant impact of these on the first fully organic crop of winter wheat. This was achieved by altering the proportions and species of green manuring and cash cropping in each strategy. In the third year winter wheat was grown across the entire experimental area as a test crop, to assess the effect of the different strategies on yield and quality of the first organic harvest. As the wheat crop was the first eligible for organic premiums, the yield heavily influenced the overall profitability of each strategy.

The conversion cropping strategies as described in Table 1 produced experimental combine harvested yields (for those crops with a commercial market) as shown in Table 2. The within field variation in yields measured in the experiment is also presented in Table 2 to allow an analysis of the effect of likely yield variability on gross margin, thereby accounting for an element of risk in the organic conversion. The two undersown wheat crops grown in the first year of conversion (UWRC, UWBP) failed, and so there is no yield to report. Organic wheat following WHBE and OABE had the most variable yields of all strategies, while organic wheat following RCRC and CSRC had the least variable yields. Gross margins produced from each strategy for each year of conversion cropping (years 1 and 2), and the first fully organic year (year 3) are given in Table 3. In-conversion gross margins were calculated on the basis of conventional crop prices (Nix, 2002), while organic wheat gross margins used premium prices (Lampkin *et al.*, 2002) as detailed in Table 4. To facilitate the comparison of strategy performance the annual gross margins were averaged over the three experimental years and a mean annual gross margin calculated. All crops are assumed to be eligible for Area Aid Payments (AAP), set-aside, or in the case of red clover seed, seed production aid. Organic Farming Scheme payments were also included in gross margins, according to rates outlined above[4]. For comparative purposes gross margins in the absence of any subsidies (AAP or OFS) are also presented in *italics* in Table 3.

In the first year of conversion a high yielding clover seed crop (0.42 t ha^{-1}) and a good clover seed price (£1000 t^{-1}) meant that CSRC generated the highest gross margin of all strategies (£705 ha^{-1}). Due to low yields, the gross margins of other strategies with a commercial crop in the first year (UWRC, WHBE, OABE and UWBP) were not as high as anticipated: in particular UWRC and UWBP generated low gross margins due to total crop failure. However, the spring oat gross margin (OABE; £436 ha^{-1}) was not dissimilar to a conventional gross margin of £440 ha^{-1} (Nix, 2002), due to the lower variable costs associated with in-conversion crop production. RCRC and VEVR strategies relied entirely upon set-aside and OFS subsidies for income, but VEVR gross margin was lower than RCRC due to higher seed costs. In the complete absence of any subsidies (no AAP or OFS) the ranking of relative gross margins is identical to the ranking of gross margins with subsidies. Only CSRC had a positive gross margin in the absence of subsidies, while OABE gross margin was near neutral.

In the second year of conversion the greatest gross margins were generated by the two bean crops: WHBE and OABE. Indeed, bean gross margins were similar to, or more than, a typical conventional bean gross margin of £445 ha^{-1} (Nix, 2002). In the absence of subsidies the near-neutral barley-pea intercrop gross margin shows that the intercrop yield was only just sufficient to offset the variable costs of production.

[4] As WHBE, OABE and UWBP may not qualify (see note to Table 1) this would need to be taken into account before choosing these strategies. Currently the gross margin analysis presented assumes that these strategies would qualify and be eligible for OFS conversion payments.

Table 1. The seven conversion cropping strategies all followed by winter wheat in the first organic year.

Strategy	First Year Conversion	Second Year Conversion	First Organic Year
RCRC	Red clover-ryegrass green manure	Red clover-ryegrass green manure	Winter Wheat
VEVR	Vetch green manure	Vetch-rye green manure	Winter Wheat
CSRC	Red clover for seed production	Red clover-ryegrass green manure	Winter Wheat
UWRC	Spring wheat undersown with red clover	Red clover green manure	Winter Wheat
WHBE*	Spring wheat	Winter beans	Winter Wheat
OABE*	Spring oats	Winter beans	Winter Wheat
UWBP*	Spring wheat undersown with red clover	Spring barley - Spring pea intercrop	Winter Wheat

* These strategies may not be legitimate as they may not be considered to contain fertility-building phases in either year of conversion (UKROFS, 2001).

Table 2. Conversion crop and organic winter wheat yields, and yield variation (n=4).

Strategy (Yr 1,2,3)	Crop	Yield (t ha^{-1})	s.d. (t ha^{-1})	Yield +1 s.d.	Yield -1 s.d.
CSRC (1)	Clover seed	0.42	0.059	0.48	0.36
UWRC (1)	u/s wheat	0.00	-	-	-
WHBE (1)	Wheat	0.24	0.109	0.35	0.13
WHBE (2)	Beans	1.96	0.656	2.61	1.30
OABE (1)	Oats	1.39	0.257	1.64	1.13
OABE (2)	Beans	2.38	0.697	3.08	1.68
UWBP (1)	u/s wheat	0.00	-	-	-
UWBP (2)	Barley-Pea	2.96	1.92	4.88	1.04
RCRC (3)	Organic wheat	5.28	0.951	6.23	4.33
VEVR (3)	Organic wheat	3.48	1.643	5.12	1.84
CSRC (3)	Organic wheat	4.53	0.759	5.29	3.77
UWRC (3)	Organic wheat	4.27	1.344	5.62	2.93
WHBE (3)	Organic wheat	3.08	2.432	5.51	0.65
OABE (3)	Organic wheat	3.38	2.742	6.12	0.64
UWBP (3)	Organic wheat	2.82	1.612	4.44	1.21

Table 3. The annual gross margins (£ ha^{-1}) of the conversion strategies and of organic wheat, and the strategy mean annual gross margins, calculated with subsidies (AAP + OFS) and *without subsidies* (-AAP, -OFS).

Strategy	First Year Conversion		Second Year Conversion		First Organic Year (wheat)		Strategy Mean Annual GM	
RCRC	†374	*-78*	†362	*0*	1161	*884*	632	*269*
VEVR	†332	*-120*	†271	*-91*	828	*551*	477	*114*
CSRC	705	*398*	†362	*0*	1022	*745*	696	*362*
UWRC	312	*-140*	†362	*0*	975	*698*	550	*186*
WHBE	386	*-66*	433	*37*	755	*478*	525	*150*
OABE	436	*-16*	470	*74*	810	*533*	572	*197*
UWBP	312	*-140*	371	*9*	707	*430*	463	*100*

† Indicates crop is eligible as set-aside

Table 4: Conventional and Organic Prices (£ per tonne) and Price Sensitivity

Crop	**Baseline Price**	**+20%**	**+50%**	**-20%**	**-50%**
Spring wheat	80	96	120	64	40
Spring barley	68	81.6	102	54.4	34
Spring oats	67	80.4	100.5	53.6	33.5
Red clover seed	1000	1200	1500	800	500
Winter beans	87.5	105	131.25	70	43.75
Spring peas	87.5	105	131.25	70	43.75
Organic wheat	185	222	277.5	148	92.5
Organic beans	200	240	300	160	100
Organic oats	160	192	240	128	80

In the first organic year gross margins reflected the yields of the organic wheat crop, hence RCRC had the highest gross margin of £1161 ha^{-1}, CSRC and UWRC second and third highest respectively. At £707 ha^{-1} and £755 ha^{-1} respectively, UWBP and WHBE had the lowest gross margins. With the exception of UWBP and WHBE, all organic wheat gross margins compared favourably with the published average figure of £818 ha^{-1} (Lampkin *et al.*, 2002), and all were higher than the typical conventional figure of £591 ha^{-1} (Nix, 2002) due to the price premium and lower variable costs. Overall, the organic wheat gross margins were higher than any individual crop gross margin during the conversion, and even without subsidies all the organic wheat gross margins were positive, illustrating the importance of organic price premiums to crop gross margins.

Averaged over the three years of study CSRC had the highest mean annual gross margin of £696 ha^{-1}, due to the lucrative clover seed crop in the first year of conversion and high organic wheat yield. The high organic wheat yield and low variable costs during conversion meant RCRC had the second highest strategy mean annual gross margin of £632 ha^{-1}.

It is recognised that average results from one experiment may not, in isolation, provide robust results upon which to base business decisions. To address this concern the robustness of the gross margins was analysed by conducting sensitivity about conversion crop yields (± 1 s.d.) and conventional prices (± 20% and 50%) (Figure 1). Under this sensitivity analysis the ranking of strategies according to gross margin changed slightly: CSRC and RCRC mean annual gross margins remained highest and second highest respectively, under all conditions; UWRC mean annual gross margin outperformed OABE with a decrease in yields by 1 s.d. or with a 50% fall in prices; WHBE mean annual gross margin was greater than UWRC with a 50% increase in prices; and UWBP mean annual gross margin was greater than that of VEVR under all yield and price increases, but lower under all yield and price decreases.

It is also instructive to examine sensitivity about the first organic wheat yields (± 1 s.d.) and organic prices (± 20% and 50%). Figure 2 shows that the mean annual gross margins of all strategies change, and the ranking of strategies by mean annual gross margin is affected to a greater extent than through sensitivity analysis of the conversion crops. The CSRC strategy mean annual gross margin again remains the highest under all sensitivity conditions, however, the large variation in organic wheat yield associated with OABE strategy means that with yield increases of 1 s.d. its mean annual gross margin becomes second highest, above RCRC, the only occasion studied when this occurs. In all other conditions OABE and UWRC mean annual gross margins are very similar, usually third or fourth highest. UWBP strategy mean annual gross margin is lowest in all conditions, except a 50% decrease in prices, when it is slightly higher than that of VEVR strategy.

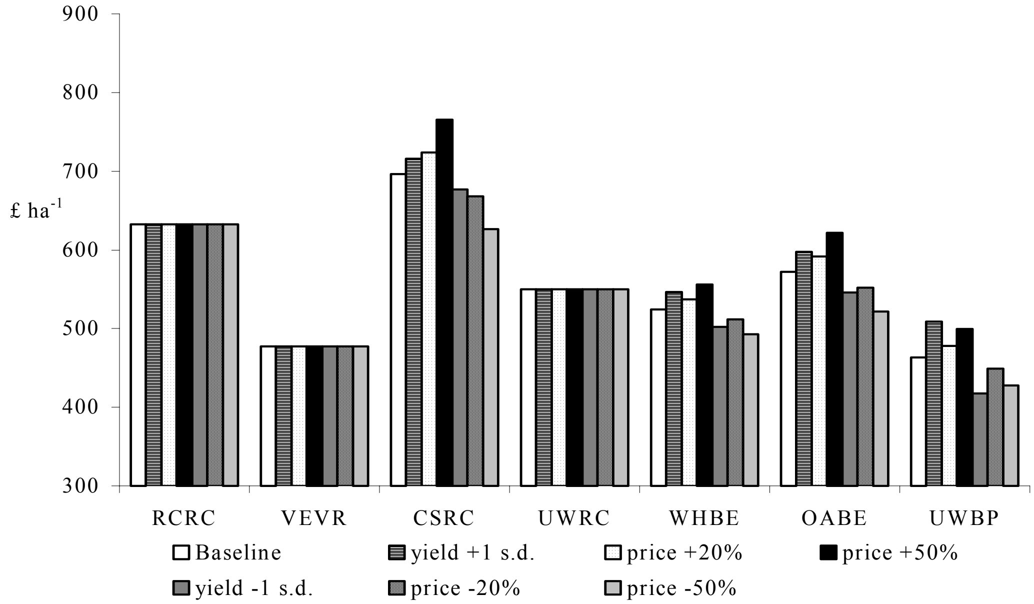

Figure 1. Sensitivity of strategy mean annual gross margins to changes in conversion crop yields, and conventional prices.

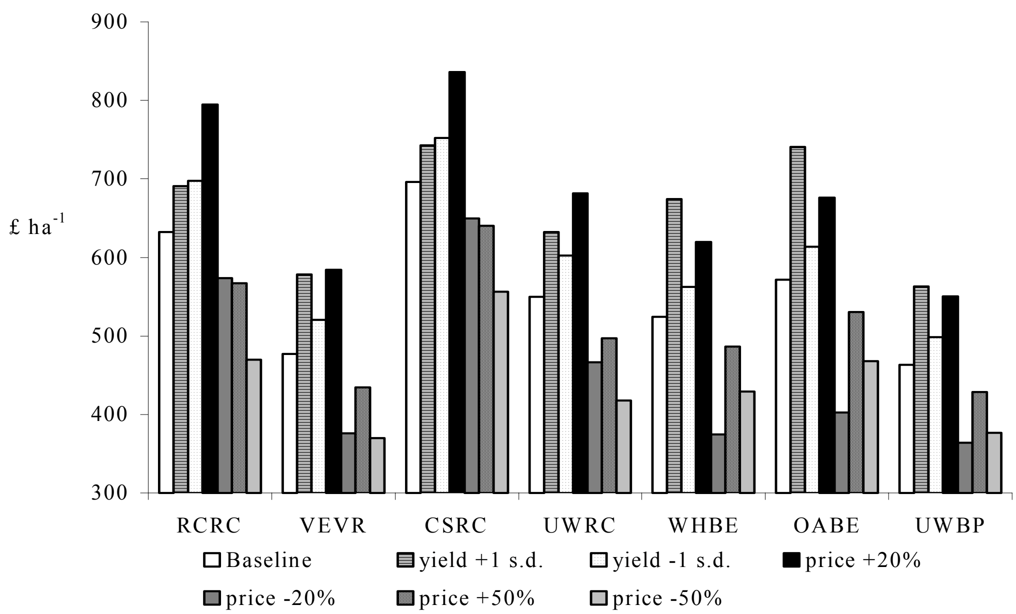

Figure 2. Sensitivity of strategy mean annual gross margins to changes in organic wheat yields, and organic prices.

With the potential changes to support payments it is also useful to examine strategy mean annual gross margins given the separate and combined absence of AAP and OFS subsidies (Figure 3). Together these subsidies contribute approximately £360 ha^{-1} to the mean annual gross margins of each strategy; thus their complete removal has a substantial effect. Area aid payments are greater in value than OFS subsides, which diminish in value over the five years from the start of conversion that they cover as noted earlier. Thus removal of AAPs (which the suggestions under the MTR would *de facto* produce) would have more of an impact on the organic conversion than the removal of the OFS. In the absence of all subsidies CSRC and RCRC strategies still generate modest mean annual gross margins of £362 ha^{-1} and £269 ha^{-1} respectively, due to high crop yields and low variable costs during conversion. The mean annual gross margins of the remaining strategies are under £200 ha^{-1}, and net margins are therefore unlikely to be above zero. Under the Organic Action Plan (DEFRA, 2002a), the government are to introduce an organic production subsidy, amounting to £30 ha^{-1} for five-year production contracts, to reward farmers for the benefits that organic farming methods are believed to provide to the wider public. For newly converted land this sum would boost the OFS subsidy of £50 ha^{-1} in the first organic year, and help offset any losses (relative to conventional production) incurred during the conversion period.

In summary the CSRC strategy provides the highest mean annual gross margin but is dependent upon securing a specialised seed production contract. Given current AAP and OFS payments, RCRC, providing the second highest gross margin is thus likely to remain an appropriate strategy choice for most farmers. In the absence of AAPs, RCRC will remain popular, not through the financial incentive of set-aside payments, but due to the enhanced yield of the first organic crop post conversion. OABE is also a potential conversion strategy if changes to organic conversion rules were made to allow such strategies to qualify for OFS payments.

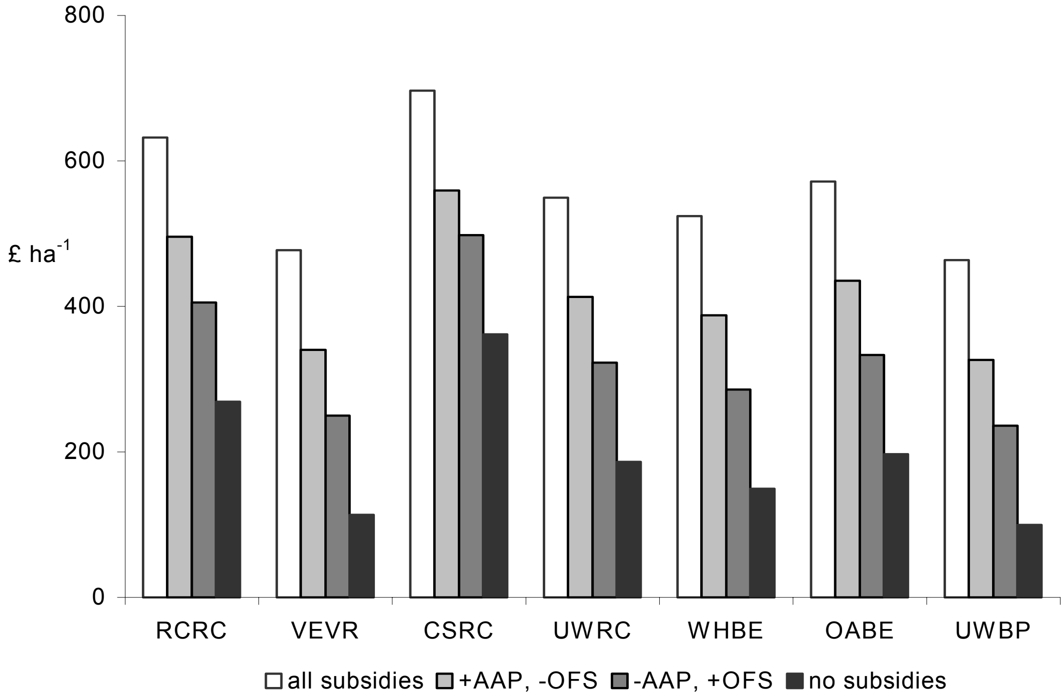

Figure 3. Strategy mean annual gross margins calculated with all available subsidies, and in the individual and combined absence of AAP and OFS subsidies.

Fully organic and conventional rotations

Using published gross margin data (Lampkin *et al.*, 2002), a typical stockless organic rotation of winter wheat, winter beans, spring oats and red clover-ryegrass green manure would generate an average gross margin of £571 ha^{-1}. By way of comparison, the conventional rotation in place on the experimental land in this study prior to conversion would generate an average gross margin of £478 ha^{-1}, according to published figures (Nix, 2002). The £30 ha^{-1} organic production subsidy would increase the difference between these gross margins to approximately £130 ha^{-1}, a substantial sum. This is however, only an average figure, and there is likely to be much greater yield variability with organic production compared to conventional cropping. Furthermore, the market for organic produce is relatively small, and whilst nationally demand may outstrip supply, on a local level growers may find it difficult to achieve the price premiums assumed in this analysis. With this in mind, organic prices (or indeed organic crop yields) have to fall by approximately 20%, before the organic and conventional rotation gross margins noted above reach parity. Some growers may consider this margin too narrow to outweigh the potential uncertainty associated with organic yields and prices, especially given that these average figures are not necessarily borne out in reality. For example, in a comparison of conventional, organic and integrated crop management (ICM) systems, while organic wheat was found to be the highest grossing crop of all systems, the organic rotation as a whole generated the lowest average gross margin, because of the loss-making fertility-building phases (Higginbotham *et al.*, 1996). In a similar study Leake (1996) compared profitability of organic, ICM and conventional rotations using experimental data for organic and ICM rotations and standard data in the conventional rotation. Within the stockless rotation organic wheat gross margins of up to £1300 ha^{-1} were achieved through a combination of good yields (5.2 t ha^{-1} five-year average) and price premiums. However, in agreement with the findings of Higginbotham *et al.* (1996), stockless organic production was least profitable when compared over the whole rotation, attributed to occasional crop failure, and to the costs of conversion.

While a gross margin analysis provides a useful measure for comparing alternative conversion cropping strategies, the fixed costs associated with each strategy must also be considered before decisions can be made. In both the first and second years of the conversion the different cropping strategies required different levels of labour and machinery resources, resulting in different fixed costs. In addition the timing of resource use may be a critical factor in determining the most appropriate strategy, for example, some strategies (VEVR, UWRC, WHBE, OABE and UWRC) were spring-sown in the first year, while others sown in autumn when demands on labour and machinery are likely to be at their height. In a farm business situation these crucial aspects must be considered. The scope of this paper has been to present gross margin information to help inform farmer decision making as opposed to testing the full economic and resource consequences of these strategies within an example farm business content.

Conclusions

Alternative conversion strategies to the typical two-year red clover-ryegrass green manure have been outlined that include commercial conversion cropping to generate income and hence reduce the potential pressure on cash flow associated with conversion. The yields and gross margins of these conversion strategies and the subsequent organic wheat crops have been presented. Results from this study indicate that this increased income during conversion may not be sufficient to offset the lower income generated by the first organic crop (winter wheat) grown after these strategies. Thus, in the absence of a red clover seed market, two years' red clover-ryegrass green manure is the best choice for a risk-averse individual, on the basis of gross margins. However, sensitivity analysis about organic wheat yields shows that growing oats followed by beans may also be a suitable strategy. This strategy has a more even distribution of income over the three years of study than two years' red clover-ryegrass green manure; important where stable cash flow is a priority. However, under current regulations this strategy may not be considered a legitimate conversion strategy, as it does not contain a fertility-building phase in either year of conversion.

As in conventional production, the conversion strategy and organic wheat gross margins are dependent on the availability and level of subsidies, and organic production is unlikely to be profitable in the total absence of support. However, the future for organic subsidy seems somewhat certain, since there is no indication that OFS payments are to be withdrawn, and an organic production subsidy is to be introduced in line with the Government's move towards environmentally-linked payments.

When averaged over the whole rotation organic production compares well to conventional in GM terms due to high price premiums and low variable costs. However, these average figures mask the greater yield variability and risk of crop failure in organic systems, which can reduce income and increase uncertainty about income levels. The performance of these conversion strategies would vary on a farm-by-farm basis. Thus the choice of conversion strategy must be considered bearing in mind the specific circumstances on the farm in question, including existing enterprise mix and farm business situation, e.g. the availability of investment capital, farm size, topography and target long-run organic rotation.

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