Constraints to the sustainability of a stockless arable rotation

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Summary

The sustainability of an organic stockless arable rotation on a fertile soil in eastern England was assessed from 1990 to 2005. The good water and nutrient holding characteristics of the silty clay loam soil were well suited to a stockless organic rotation. Fertility-building clover crops were the most difficult to establish, and failed completely in some years despite one or two re-sowings. Crop yields were good, particularly for cereals, with an average for winter wheat of 7 t ha^{-1}. Crop yield did not show any particular trend with time; there was no evidence of either a post-conversion adjustment period, or a fall in yield due to declining fertility. High organic crop prices in the 1990s, resulted in significantly higher gross margins than from comparable non-organic farms. However, falling organic crop prices from 2000 resulted in profitability only similar to non-organic. Supply of N, P and K was probably not a major limitation to crop growth and yield. However, in the longer term, additions of sustainable sources of plant-available phosphorus and potassium would be necessary, even on the nutrient retentive and potassium rich soil. Effective mechanical weeding was difficult on the silty soil. The rotation favoured perennial weeds, particularly creeping thistle which increased progressively despite efforts at control with mechanical and hand weeding.

Key words: Organic farming, stockless, rotation, weeds

Introduction

Organic farming systems traditionally involve a mix of crops and livestock with nitrogen supplied largely from atmospheric fixation by clovers in grass/clover leys managed by grazing and harvesting for hay and silage. However, across northern Europe, conventional agriculture has developed a specialised structure with many areas having no livestock or knowledge of facilities to support livestock. In a stockless organic rotation, the absence of livestock, manures and long-term grass/clover leys poses significant challenges in terms of nitrogen supply and management, supply of phosphorus and potassium, and the control of weeds, pests and diseases. There is also an economic challenge from having a substantial proportion of the crop rotation in dedicated fertility building crops with no saleable output. The objective of this study was to assess the economics of conversion to stockless arable organic production, to identify and research limitations to sustainability and to demonstrate the system to farmers and advisers.

Methods

Site and study design

The study was located on the ADAS Research Centre at Terrington St Clement, Norfolk, UK (52° 44' N, 0° 17' E). The soil is a deep stoneless silty clay loam of the Wisbech series (Cormack, 2006). The project was an unreplicated study with field-scale plots. There were five plots, each of 2 ha, each in a different phase of a five-year rotation. Conversion started in 1990. This design, with no replication within-year, whilst allowing more meaningful crop husbandry and economic evaluation than a conventional small-plot replicated experiment, did limit statistical analysis. This was a deliberate choice as economic evaluation and demonstration were the principal initial objectives of the project. Despite this limitation, it has provided a long-term data-set gathered under realistic conditions that gave useful indicators of crop performance in a stockless rotation. The crop sequence was: white clover (fertility building crop) → potatoes → winter wheat → spring beans → spring cereal (undersown with clover).

The fertility-building crops were mown between one and three times per year in response to growth rate, and the mowings were left as a mulch. All seed, apart from an approved proportion of the white clover, was organically grown. Aluminium calcium phosphate (14% P) ("Redslaag") was applied once per rotation from 1995 at 625 kg ha^{-1}. No manures, composts or other fertilisers were applied. No irrigation was applied.

Above-ground dry matter, and nitrogen accumulation of the fertility-building crops was measured. For all crops, samples of harvested produce were analysed for nitrogen, phosphorus and potassium content, and offtake calculated. Soil was sampled each year and was analysed for available P (Olsen's method), available K (ammonium nitrate extraction), and carbon. Crop and rotation gross margins were calculated using actual sale prices where possible.

Results and Discussion

Fertility-building crops

Of all the crops grown post-conversion, fertility-building crops have been the most difficult to establish. Over the life of the project, clover failed to successfully establish in four of the eleven years from 1995 to 2005, even when re-sown in some years. Vetch was sown in spring as a (reputedly) rapidly-growing replacement in three of the years but it was slow to establish, competed poorly with weeds and had considerably lower accumulated nitrogen in the mulched foliage. The mean accumulated nitrogen in vetch was 102 kg ha^{-1} (range 90 to 121), whereas in clover it was 175 kg ha^{-1} (range 0 to 274). Until 1995, clover was direct-sown in autumn after harvest of the preceding cereal crop. From 1996, with establishment of full crop rotation on all five plots, clover was undersown in a spring cereal. Each method suffered particular problems; direct sown crops start growth well in autumn but were susceptible to damage from *Sitona* spp. weevils and frost. Undersown crops were more susceptible to drought and slug damage. Growth of established crops was affected by variation in rainfall, and by attack from pests such as *Sitona* spp. weevil and stem nematode (*Ditylenchus dipsaci*).

Despite the poor performance of some of the fertility-building crops, this was not clearly reflected in the performance of following crops. For instance, the failed clover in 1996 was followed by above-average yields of potatoes in 1997 and of winter wheat in 1998. This illustrates both the nutrient retention capacity of the soil at Terrington and the over-riding impact of environmental conditions on organic crop performance, particularly on a fertile soil (Cormack *et al*., 2003).

Crop performance

Winter wheat yield was good, with an average of 7.0 t ha^{-1}. Yield was relatively consistent, and reflected environmental conditions, with lowest yields in the very dry 1995 and the wet and dull 1997 and 2001. Grain nitrogen content ranged from 1.7% (1995 and 1997) to 2.2% (2003). Foliar diseases were present only at low levels, and no fungicides were applied.

Potato total (mean 35 t ha^{-1}) and saleable yields (mean 23 t ha^{-1}) were very variable, reflecting effects of rainfall both directly on growth and yield, and indirectly on the activity of slugs and blight.

Beans generally established and grew well with yields of over 3 t/ha in all but two years. Yield was reduced in 1995 by drought, in 1997 by poor pollination and pod set in a very dull June, and in 2004 and 2005 by weeds.

On average (4.2 t ha^{-1}), the spring cereal yielded considerably less than the winter wheat. This was expected as it was at the end of the crop sequence when nitrogen availability would be least. Foliar disease levels were low, and as for winter wheat, were unlikely to have been limiting to yield.

Profitability

The stockless organic rotation was substantially more profitable than comparable Farm Business Survey non-organic farms during the 1990s. From 1999, relative profitability declined, principally due to a decline in organic crop prices. A similar pattern of profitability was reported by a concurrent farm-scale stockless study in the east midlands (Anon., 2003).

Nutrient supply

The relative stability of cereal yields with time suggests that the nitrogen supply was in balance. The total mean offtake of nitrogen over a rotation was 427 kg ha^{-1}. Net nitrogen fixation was not measured, so that cannot be confirmed. However, this does suggest that the measure of gross nitrogen accumulation in the fertility-crop mulched foliage (which ranged from 0 to 274 kg ha^{-1}) considerably underestimated the net nitrogen fixation.

There were marked variations in available phosphorus (P) in the soil between seasons. Available P tended to continue to decline throughout the study, but at a slower rate after 1995 and with marked seasonal fluctuations. By 2005, levels were between 10 and 16 mg l^{-1}, in Index 1 for Olsen's P, and unlikely to be limiting to plant growth.

In contrast to phosphorus, available potassium (K) did not show a decline post-conversion. By 2005, available K averaged 185 mg l^{-1}. This was similar to the levels in 1990, and was well above levels limiting to crop growth. As no K has been added, the substantial offtake, particularly from potatoes, has presumably been replaced by release from clay minerals in the soil. There was a very marked seasonal effect showing the importance of using changes over time, rather than spot measures, to assess change in soil fertility.

Soil carbon showed, on average, a trend for a progressive small increase (from 1.1% on 1990 to 1.4% in 2005).

Weeds

Greatest numbers of weeds were associated with spring-sown cereals and beans, and with failed fertility-building crops, where crop competition was least. Typical weeds of spring cropping were rare in the earlier years, but they became more prevalent in later years.

Much more obvious were the increases in the perennial species creeping thistle (*Cirsium arvense*) and docks (*Rumex* spp.), particularly the former. It spread progressively across all plots until in 2005 it was present across the whole study area. The relentless increase in creeping thistles suggests that the crop rotation was inherently favourable to them. The decline in shoot numbers seen under dense clover suggests that the main encouragement for thistles is a lack of effective crop competition inherent in the crop sequence.

Conclusions

The good water and nutrient holding characteristics of the silty clay loam soil were well suited to a stockless organic rotation, particularly for autumn sown wheat. The soil was less suited to the establishment of small-seeded and spring-sown crops. Fertility-building clover crops were the most difficult to establish, and failed completely in some years despite one or two re-sowings. Because of the soil texture, it was often too wet to travel when crops and weeds were suitable for mechanical weeding. This contributed to the increased weed problems in later years.

Crop yields were good in comparison with organic standard yields, particularly for cereals. Crop yields through the project did not show any particular trend with time. There was no evidence of either a post-conversion adjustment period, or a fall in yield due to declining fertility. High organic crop prices in the 1990s, and good yields, resulted in significantly higher gross margins than from comparable non-organic farms. However, lower organic crop prices in the new century removed that advantage making conversion to stockless organic a less attractive option for farmers. The introduction of the Single Payment Scheme in 2005 has further changed the economic picture making the inclusion of high proportions of dedicated fertility-building crops look even less attractive.

In the longer term, additions of sustainable sources of plant-available phosphorus and potassium will be needed in a stockless rotation, even on nutrient retentive and potassium rich soils. This is an industry-wide issue as many mixed and livestock organic farms are only in positive P and K balance because of nutrients imported in animal feeds from other organic farms, some stockless.

The main biological constraint was weeds. The rotation favoured perennial weeds, particularly creeping thistle which increased progressively despite efforts at control with mechanical and hand weeding. Strategies to avoid domination by perennial weeds should be put in place at the start of conversion. That would be more likely to succeed in the long term rather that trying to contain a well-established population at a manageable level. A new Defra-funded study (OF0367) will take this forward.

New designs of stockless rotation are needed that have better integration of fertility-building, ideally with all crops earning revenue, and that are more competitive with perennial weeds.

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