The long-term agronomic performance of organic stockless rotations

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ABSTRACT

Two long-term experiments were established with the aim of evaluating the agronomic and economic performance of organic stockless rotations. In total, four different rotations were evaluated at two sites in the south (Elm Farm Research Centre) and east (ADAS Terrington) of England. All of the rotations included either a one or two-year red clover green manure crop to provide nitrogen for subsequent crops and it was found that this was sufficient to support three or four years of arable cropping. Over a period of eleven years at EFRC and five years at ADAS Terrington, there was no evidence of a decline in crop yield, although there were significant year-to-year variations. Crop yields were generally equivalent to or greater than average organic yields. Levels of soil available P and K was maintained at both sites at non-limiting levels. Pest and diseases were not problematic, but perennial weeds posed the most significant problem.

Keywords: organic farming; stockless; arable crops

INTRODUCTION

Rotations are the primary means of maintaining soil fertility and achieving weed, pest and disease control in organic crop production systems. For conventional arable farms the uptake of organic farming is severely limited by the capital investment required to introduce a livestock enterprise as part of a typical mixed organic system. This has provided an incentive for the development of organic systems without livestock (a 'stockless' system), but there are a number of challenges relating to rotation design, e.g. nutrient supply, that need to be addressed and resolved before such systems can be considered agronomically and economically viable in the UK. It was the aim of the research established by Elm Farm Research Centre (EFRC) and ADAS to address these challenges.

MATERIALS AND METHODS

Two long-term experiments were established by EFRC and ADAS Terrington. The experiment established by EFRC comprised three, four-year rotations (Table 1) in three fully randomised blocks. Every course of every rotation was present in each year giving a total of 36 20m x 12m (0.02 ha) plots. Prior to establishment of the experiment in 1987, the field had been in a long-term grass ley. The data presented below includes eleven years data, i.e. nearly three complete cycles of rotation. The experiment established by ADAS took a different approach. In this case, the experiment was non-replicated but used 5 field-scale plots (2 ha), each running the five-year rotation (Table 1). Prior to establishing the experiment in 1990, the field was managed as part of a conventional arable rotation. Red clover was established during the two-year conversion period before the first organic arable crop (potatoes) was established. The data from ADAS Terrington includes the first cycle of rotation only (2 years in-conversion red clover + 4 years arable cropping).

The soil type at EFRC is a Wickham series clay loam, whilst at ADAS Terrington the soil type is an Agney series silty clay loam. The average annual rainfall is 710 mm yr^{-1} at EFRC and 584 mm yr^{-1} at ADAS Terrington.

Table 1. Rotations in the stockless experiments

	Course of rotation				
Rotation	**1**	**2**	**3**	**4**	**5**
EFRC **A**	Red Clover	W. Wheat	W. Wheat	S. Oats	
EFRC **B**	Red Clover	Potatoes	W. Wheat	W. Oats	
EFRC **C**	Red Clover	W. Wheat	W. Beans	W. Wheat	
ADAS	Red Clover[1]	Potatoes	W. Wheat[2]	S. Beans[2]	S. Wheat

[1] Two-year red clover during conversion, thereafter one-year.
[2] Followed by stubble turnip over-winter cover crop

For both EFRC and ADAS, cultivations, sowing, planting and in-crop weed control were carried out using standard farm equipment. The harvesting of the cereal crops and the field beans was carried out using a trial plot combine. For potatoes, test rows were harvested to establish final yield.

A number of parameters have been continually assessed at both sites. For the green manure crops, dry matter (g m^{-2}) and nitrogen accumulation (kg ha^{-1}) were assessed. For the cash crops, yield, quality, nutrient off-take, emergence, weed dry matter (g m^{-2}), pests and disease were assessed. In terms of soil, assessments were made of nutrient status including mineral nitrogen and bulk density.

RESULTS AND DISCUSSION

Green manures

The red clover crops at both sites were cut and mulched approximately 3 to 4 times per season. Overall at EFRC, there were no significant differences between rotations in terms of the above ground N accumulation of the red clover green manure crops. On average, the red clover accumulated approximately 275 kg N ha^{-1}. There was, however, significant year-to-year variation. At ADAS Terrington, the red clover accumulated 682 kg N ha^{-1} on average over its two-year duration. Stem nematode, whilst not a problem at EFRC, has caused poor clover growth in patches at ADAS Terrington. To mitigate this, ADAS are currently looking to replace pure red clover with white clover and Lucerne.

Arable crops

At both sites, there was no significant decline in the yield of the arable crops over the eleven-year period at EFRC and three- to five-year period, depending on the crop, at ADAS Terrington. There were, however, considerable variations between years. In terms of the wheat crops, initial plant density was shown to be the most important factor affecting final yield at EFRC. The average yield of the wheat crops were comparable with the average figures reported by Lampkin & Measures (2001) in the case of EFRC and considerably greater than the average at ADAS Terrington (Table 2). The exception to this was the second wheat in rotation A (A2) at EFRC, which demonstrated the lowest yield, and was considerably below the organic average of 4 t ha^{-1}. The spring oats at EFRC performed poorly, which was a reflection of the unsuitability of the site for spring cropping. In terms of potatoes, the yields at EFRC were generally low, whilst at ADAS Terrington the yields were equivalent to the organic average. It was very clear from both sites that the yield of potatoes in individual years varied markedly. This was mainly due to variations in rainfall combined with the lack of ability to irrigate, although potato blight and slug damage also contributed to this variation. At both sites, the bean yields (winter and spring) were either equal to or greater than the organic average (Lampkin & Measures, 2001).

Table 2. Average crop yields for the EFRC and ADAS experiments

Site	Rotation/Course	Crop	Previous Crop	[1]Ave. Yield t ha^{-1}
EFRC	A2	W. Wheat	Red Clover	4.29
	A3	W. Wheat	W. Wheat	2.64
	A4	S. Oats	W. Wheat	2.03
	B2	Potatoes	Red Clover	[2]29.35
	B3	W. Wheat	Potatoes	4.29
	B4	W. Oats	W. Wheat	3.19
	C2	W. Wheat	Red Clover	3.75
	C3	W. Beans	W. Wheat	4.10
	C4	W. Wheat	W. Beans	3.99
ADAS	2	Potatoes	Red Clover	[2]37.16
	3	W. Wheat	Potatoes	7.22
	4	S. Beans	W. Wheat	3.10
	5	S. Wheat	S. Beans	4.10

[1] Yield at 85% DM. [2] Total Yield.

Soil

Organic matter

At EFRC the soil organic matter prior to the start of the experiment was approximately 3.2%. However, after the first three years, the levels of soil organic matter dropped to around 2.5%, at which they have remained for the remaining eight years. This is not surprising given the experiment followed a long-term grass ley, with the increased intensity of cultivation serving to mineralise organic matter. The fact that it has stabilised at 2.5% suggests that the system is now in equilibrium. In contrast, soil organic matter levels at ADAS Terrington have risen slightly over the course of the experiment from approximately 2 to 2.5%. Again, this might be expected given that a greater quantity of biomass (red clover) is incorporated compared with its history of conventional management.

Soil available phosphorus and potassium

At EFRC, the levels of available soil P (*ca*. 55 mg l^{-1}) and K (*ca*. 140 mg l^{-1}) have been maintained over the duration of the experiment. Applications of rock phosphate were made to the red clover plots according to soil analysis, but there have been no inputs of potassium. At ADAS Terrington, soil available P levels have declined from approximately 27 mg l^{1} to 15 mg l^{1} since the start of the experiment. To address this, applications of aluminium calcium phosphate (14% P) were made following the spring bean crop. However, this decline may simply be due to utilisation of the large P surplus inherited from conventional farming, and the reaching of equilibrium under organic management. Levels of available soil potassium have been maintained at approximately 200 mg l^{1} since the start of the experiment. Therefore, at both sites, it appears that the rotations can maintain adequate levels of soil available P and K.

Weeds, pests and disease

In general, pests and diseases have not been problematic for these stockless rotations. However, there have been some concerns at ADAS Terrington regarding the build-up of potato cyst nematode (*Globodera rostochiensis* and *G. pallida*). To avoid this problem, vegetables are being introduced as an alternative to potatoes to allow longer intervals between crops.

Weeds have been more problematic for these intensive arable rotations. The levels of annual weed species have increased in both experiments, although these have been adequately controlled by mechanical weeding techniques. The more serious problem is perennial weeds. Levels of perennial grasses such as couch have increased at both sites, and creeping thistle has been a particular problem at ADAS Terrington. Therefore, developments are needed for the control of these weeds to overcome the restriction of predominately arable rotations.

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