Effect of organic crop rotations on long-term development of the weed seedbank

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ABSTRACT

Changes in the weed seedbank were monitored between 1991 and 1998 in two experiments that were established to compare organic crop rotations at two sites in NE Scotland. Two rotations, replicated twice at each site, were compared and all courses of both rotations were present every year. There were relatively minor changes in weed species diversity over time, but major changes in seedbank abundance. Weed seed numbers were relatively low in rotations with a high proportion of grass/clover ley. Differences in level of seedbank across the rotation were relatively predictable at Tulloch but much less so at Woodside where factors such as the effect of the grass/clover ley seemed to play a lesser role. Other factors, such as weather and its influence on the effectiveness of weed control operations, and higher populations of ground-living arthropods, may be affecting the Woodside seedbanks.

Keywords: weed seedbank, organic farming rotations, grass/clover leys

INTRODUCTION

The choice of crop rotation is fundamental to the success of organic systems. The rotation, in particular the ratio of fertility building to fertility exploitative cropping phases, has a major influence on the yield of arable crops such as cereals and roots. In addition the rotation will influence the flora and fauna of the farm environment and impact on the aquatic and atmospheric environments. A long-term field experiment was established at each of two SAC organic farms in 1991. The objective was to compare crop rotations which differed in the proportion of fertility building crop (grass/clover ley) in the rotation. Effects on agronomic performance and on nutrient dynamics have been reported earlier (Younie *et al*, 2000; Watson *et al, 2000*) and Taylor *et al* (2002) have discussed the practical design and management issues of these experiments. This paper reports on the effects of the rotation treatments on weed seedbanks in the soil.

MATERIALS AND METHODS

Two rotations were established at each site, with all courses of both rotations appearing every year. Each rotation was replicated twice at each site. Plot sizes were 0.078ha (Tulloch) and 0.092ha (Woodside). Rates of farmyard manure application reflected the proportion of grass/clover in each rotation. Crop husbandry procedures were based on Soil Association organic standards. In addition to measurements of yield, crop quality, weed development, and soil nutrient dynamics, weed seedbank populations were measured biennially. Soil samples (approx. 1kg) were taken with a trowel to 20cm depth, always at the same position, at three locations on a diagonal transect across each plot. The treatment rotations were as follows:

	1		2		3		4		5		6		7		8
Woodside															
Rotation W1	G/C1	→	G/C2	→	O1	→	P	→	$O2_{u/s}$	→	G/RC	→	S	→	$O3_{u/s}$
Rotation W2	G/C1	→	G/C2	→	G/C3	→	O1	→	P	→	$O2_{u/s}$				
Tulloch															
Rotation T1	G/C1	→	G/C2	→	G/C3	→	O1	→	S	→	$O2_{u/s}$				
Rotation T2	G/C1	→	G/C2	→	G/C3	→	G/C4	→	O1	→	$O2_{u/s}$				

(G/C1:Grass/white clover, 1st year; G/RC:Grass/red clover; O1=Oats, first year, $O_{u/s}$= Oats undersown; S=Swedes; P=Potatoes)

RESULTS

Weed seedbank abundance

Total weed seed numbers in the seedbank, meaned over all phases of each rotation, are shown in Table 1 for each site, from the start of the experiment until the end of the 1998 season, by which time all rotations had completed at least one cycle.

Table 1. Number of weed seeds in seedbank meaned over each rotation (number of seeds/m^2 to 20cm depth).

Site	**Rotation**	**Sampling date**		
		Spring 1991 (Prior to start)	Winter 1994/95	Winter 1998/99
Woodside	W1 (38% grass/clover ley)	7354	43838	13044
	W2 (50% grass/clover ley)	7919	31783	10526
	Woodside mean	7637	37811	11785
Tulloch	T1 (50% grass/clover ley)	12583	35950	21946
	T2 (67% grass/clover ley)	15252	32133	12218
	Tulloch mean	13918	34042	17082

The seedbanks were higher at Tulloch than at Woodside, both at the start of the experiment in 1991, and in 1998. At both sites the seedbank increased dramatically between 1991 and 1994, but subsequently fell. Compared with 1991, mean weed seed numbers in 1998 were 54% and 23% higher at Woodside and Tulloch respectively. At both sites, the rotation with the higher proportion of grass/clover ley resulted in a lower seedbank, both in 1994 and in 1998. In 1998 at Woodside, the seedbank of W2 was 19% lower than W1 and at Tulloch T2 was 43% lower than T1. The seedbank in T2 was lower in 1998 than it was before the start of the experiment. However, none of the differences were significant because of the high variation within and between plots.

Table 2 shows the effect of rotations on weed seedbanks in plots immediately after the cereal crops, during the period 1994 to 1998. By 1994, three years after the start of the experiment, the effects of cropping sequence on each plot were becoming established.

Table 2. Number of weed seeds in seedbank of plots cropped with C1 and C2 cereals in the season prior to sampling (No. seeds/m^2 to 20cm depth).

Site	**Rotation**	**Sampling date**		
		Winter 1994/95	Winter 1996/97	Winter 1998/99
Woodside	W1 (38% grass/clover ley)	42700	73500	9253
	W2 (50% grass/clover ley)	22750	36550	7914
Tulloch	T1 (50% grass/clover ley)	32750	38000	32170
	T2 (67% grass/clover ley)	21000	37950	23577

Weed seed numbers in Table 2 are higher than those meaned over the whole rotation (Table 1). In Table 2, as in Table 1, the rotations with a higher proportion of grass/clover ley (W2 and T2) had consistently lower weed seedbanks than the other two rotations, emphasising the role which the grass/clover ley plays in minimising weed build-up over the rotation as a whole. The seedbanks in all courses of each rotation for 1998 are shown in Figure 1.

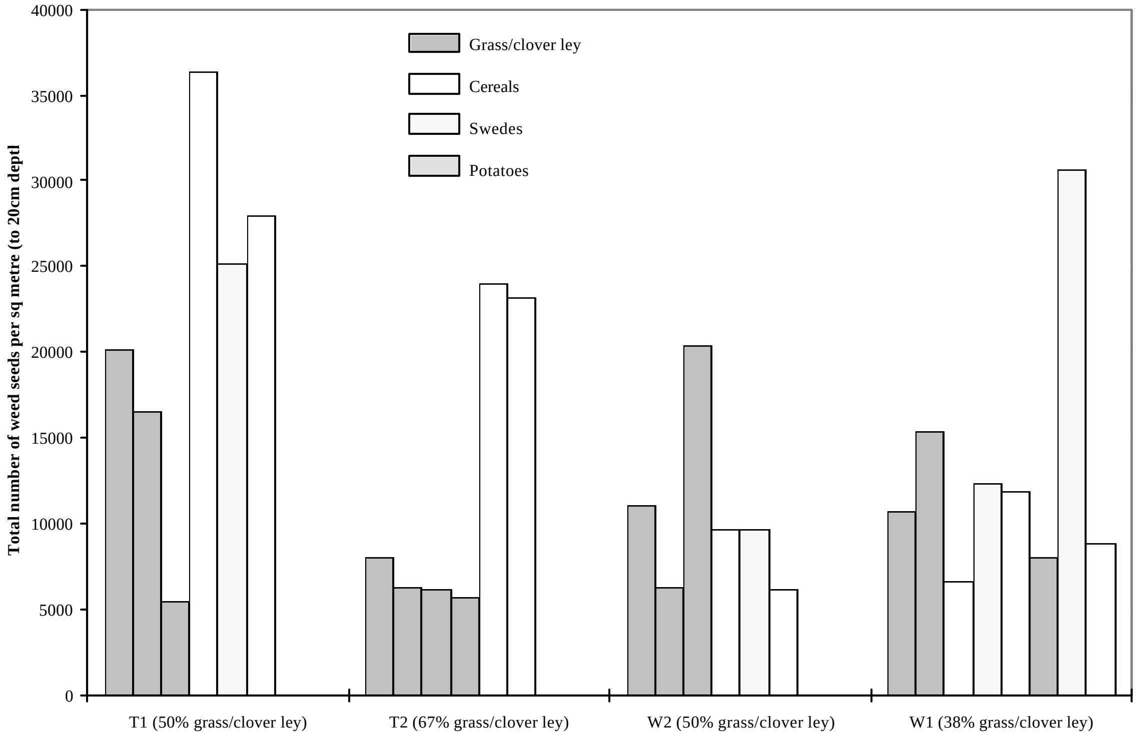

Figure 1. Mean weed seedbank in all courses in each rotation,1998.

In both Tulloch rotations, the weed seedbank in the grass/clover leys was highest in the first year ley and declined in older leys. The seedbank in the arable plots was consistently and substantially higher than in the grass/clover plots. At Woodside, on the other hand, seed numbers were less predictable. There was no consistent effect of age of ley and seedbanks in the arable plots were no higher than in the grass plots, with the exception of the swede plots in W1.

A number of factors may be contributing to these differences between sites. Woodside has a lower rainfall and the sandy soil has a lower organic matter (OM) content than the sandy loam at Tulloch. These factors result in lower crop (and weed) vigour at Woodside. Nevertheless, substantial return of weed seeds did take place at Woodside (e.g 1996 data), but other factors may have resulted in a greater reduction in the seedbank over time at Woodside than at Tulloch. These factors may include particularly effective weed control episodes (e.g. when a period of low rainfall coincides with the use of a stale seedbed or direct weed control measures in a row crop). Even when no direct weed control measures are carried out, in dry seasons weeds may germinate but later in the season suffer moisture stress and fail to set seed. This is particularly likely at the dry, sandy Woodside site, and especially in first year cereal when competition for moisture is greatest. A further factor may be the substantially higher soil arthropod populations at Woodside compared to Tulloch (Chapman, 1997). A number of the arthropod species observed at these sites were seed eating species and these could have played a role in reducing seed numbers in the soil. Further detailed analysis of the data is required to clarify the complex relationships between seedbank, soil type, climate and cropping sequence.

Weed seedbank diversity

Abundance relates to the total number of individuals in a population whereas diversity relates to the number of species in the population and the pattern of dominance within the range of species. The number of weed species found in the seedbank at Tulloch was 13 in 1991; this increased to 18 in 1994 and then fell to 12 after the 1998 season. At Woodside the number of species found was 16, 25 and 18 in 1991, 1994 and 1998 respectively. This represents only a modest increase in diversity over time. The degree of dominance of individual species within these species ranges is shown in Figure 2. It can be seen that by 1998, only four species accounted for over 90% of the seedbank at both sites.

In the K-dominance plot (Platt *et al*, 1984), high diversity is represented by a line which intercepts the Y-axis at a relatively low point and rises steadily rather than rapidly to the maximum. This is best illustrated by the curve for Woodside 1991, where 90% of the seedbank was made up of seven weed species and the most abundant species contributed 32% of the total, whilst the curve for Woodside 1998 shows that 93% of the seedbank was made up of just four species and the most abundant species contributed 41% of the total. At Tulloch the diversity of the seedbank in 1998 was somewhat greater than in 1991 when 61% of the seedbank was made up of just one species and 90% of the seedbank was made up of only three species. In 1998. the most abundant species contributed 50% of the seedbank and 90% of the seedbank was made up of four species.

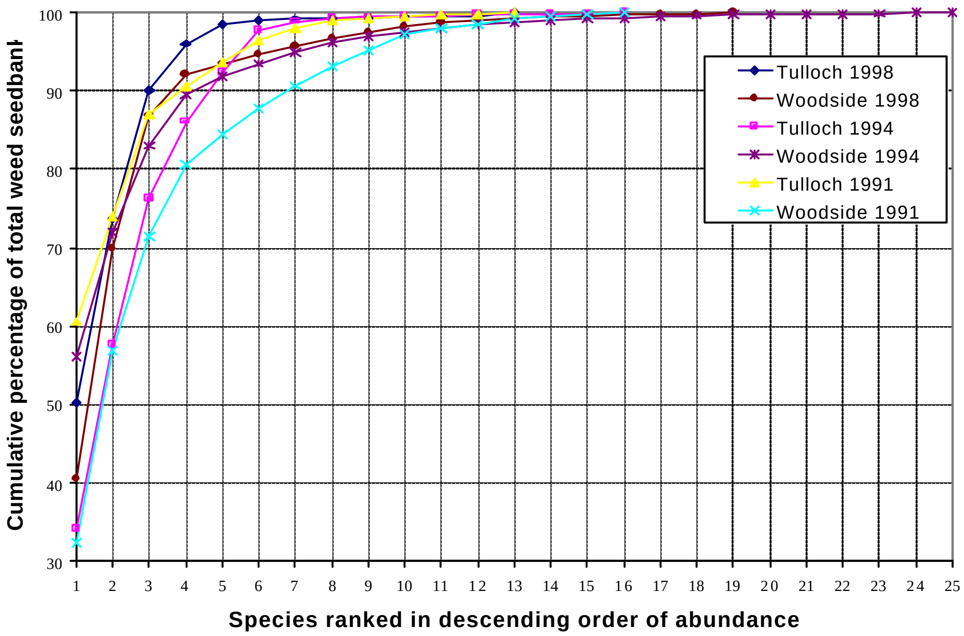

Figure 2. K-dominance plot showing the species diversity of the weed seedbanks at Tulloch and Woodside in 1991, 1994 and 1998.

The main weed species at Tulloch in 1998 were Spurrey (*Spergula arvensis*), Chickweed (*Stellaria media*), *Poa* species and Knotgrass (*Polygonum aviculare*). In contrast, the most common weed seed at the start of the experiment in 1991 was *Juncus* spp., along with Spurrey and *Poa*. At Woodside, the four main weeds in 1998 were the same as in 1991: Spurrey (*Spergula arvensis*), Fat Hen (*Chenopodium album*), *Poa* spp. and Field pansy (*Viola arvensis*).

Apart from the virtual disappearance of *Juncus* spp. at Tulloch, these are relatively small changes in species diversity. The conversion to organic production methods which commenced in 1990 involved the cessation of the use of soluble fertilisers, herbicides and fungicides, but the cropping system remained as a mainly ley/arable system in which spring cereals predominated (winter barley was previously grown occasionally at Tulloch but not at Woodside). This may explain the fact that changes in species diversity between 1991 and 1998 were relatively minor.

Nevertheless major changes in weed seed abundance occurred at these two sites and in the two rotations at each site. Whilst the reasons for some of these changes can be identified with some confidence, there are other factors affecting the seedbank, particularly at Woodside, and further analysis of the data is necessary.

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