EFFECT OF CULTIVATION METHODS ON WEED SEED DISTRIBUTION AND SEEDLING EMERGENCE

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ABSTRACT

The influence of four cultivation treatments viz. ploughing, rotary hoeing, power harrowing and no soil disturbance, on the distribution of weed seeds in the soil profile was investigated in a field trial. Weed seeds were counted by dry sieving soil samples collected from 0-5, 5-10, 10-15 and 15-20 cm depths. The density and species of weeds that emerged in field plots were also recorded at three-weekly intervals. Samples from undisturbed plots showed a linear decline with depth. Ploughing was the only treatment that caused a significant shift of seeds to the deeper profile. Ploughed plots had significantly fewer weed seedlings than other treatments, due to lower numbers of both summer grasses and broadleaf weeds. Undisturbed plots contained significantly fewer broadleaf species, and weed emergence was delayed. Implications of these results for seedbank sampling methodology and weed management strategies are discussed.

Keywords: weed seedbank, cultivation, weed emergence, ploughing, rotary hoeing.

INTRODUCTION

Understanding the biological and ecological behaviour of weeds is a pre-requisite to developing guidelines for environmentally sound weed control (Zimdahl 1995). In this respect, knowledge of the weed seedbank is especially important because it allows forecasts of future weed problems (Forcella 1992). Bioeconomic weed management models use seedbank estimates to predict weed population dynamics and competitiveness (Lybecker *et al.* 1991). This may be a good starting point for an integrated weed management programme, however, estimating seedbank size of arable weeds is difficult. We have previously studied sampling methodologies and spatial distribution of weed seeds (Rahman *et al.* 1997; 1998; 1999) but lack local knowledge on the effect of soil disturbance on seed distribution and resulting weed populations.

The distribution of weeds within fields is often spatially aggregated or patchy and this, in conjunction with various cultural factors, results in seedbanks that are spatially heterogeneous (Rew *et al.* 1996; Rew and Cussans 1997). Different types of cultivation also influence seed distribution among soil aggregates and in the soil profile. Studies of the horizontal movement of weed seeds following cultivation with different implements have shown that majority of seed moved <1 m from their source (Rew and Cussans 1997). The vertical seed movement is of greater consequence as different types of cultivation move seeds to different depths in the soil (Moss 1988; Dessaint *et al.* 1996). Weed seedling emergence and seedbank depletion are greater from seeds near the soil surface than from those more deeply buried (Zhang *et al.* 1998) because more seeds encounter conditions favourable for germination. In addition to weed population dynamics, the spatial distribution of seeds in the soil influences the degree of inter- and intra-specific competition, the level of outcrossing or inbreeding and the susceptibility of weed seedlings to insect pests and plant pathogens (Wilson 1992). The aim of this study was to investigate the influence of four contrasting cultivation treatments on the movement and distribution of weed seeds in the soil profile and the consequent emergence of weed seedlings.

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MATERIALS AND METHODS

The field experiment was conducted at the Waikato Research Orchard near Hamilton between October and December 1999. The soil was a Te Kowhai silt loam of volcanic origin (44% sand, 22% silt, 34% clay, 3.0% organic carbon and pH 5.8) and the site had been under continuous maize cropping for 10 years. In previous years the site was rotary hoed to 15 cm depth before final cultivation with a rototiller at planting. The trial site remained undisturbed after the previous maize crop was harvested in 1999.

The four cultivation treatments used in this study were ploughing, rotary hoeing, power harrowing and no soil disturbance. The plough used was a three blade mouldboard plough which inverted the top 15 – 20 cm of the soil. The rotary hoe was 2 m in width and vertically re-distributed the top 15 cm of the soil. The power harrow was 4 m wide, its tines rotated horizontally to cultivate the soil to a depth of 10 cm, and it required two passes to produce a fine tilth. After the cultivation treatments, the trial area was rolled to produce a uniform compaction. Each treatment was replicated 12 times in a randomised block design and individual plots were 6 m x 4 m.

Soil sampling

Soil samples for enumeration of the weed seedbank were taken immediately before and after the cultivation treatments. Each sample consisting of a single core from each plot was taken with a 7.5 cm diameter sampling tube to a depth of 20 cm. The sample was then divided into 0–5, 5–10, 10-15 and 15-20 cm fractions which were placed into separate plastic bags and returned to the laboratory for processing.

Seed enumeration and seedling emergence counts

In the laboratory, the soil samples were immediately oven dried at 60°C for 12 h, passed through a 4 mm sieve to remove trash and weighed. The samples were sent to the New Zealand National Seed Laboratory, Palmerston North for extraction and quantification of weed seeds by methods previously described (Rahman *et al.* 1998). Briefly, each sample was washed through a fine mesh to remove soil particles. The remainder was air dried and passed through a descending series of sieves. Whole and empty seeds were extracted by hand, identified and counted. Viability of whole seeds was determined by crushing, with only those seeds exhibiting white healthy endosperm counted as viable.

Seedling emergence counts were made using a 0.1 m^2 quadrat placed adjacent to where the soil sample was taken for seed enumeration. The first seedling count was on 3 November 1999, 3 weeks after cultivation, as soon as the weed seedlings were large enough to identify. The second and third counts were done on 24 November (6 weeks) and 15 December 1999 (9 weeks), respectively. After each count the seedlings were removed by hand.

Data analysis

All seed counts were adjusted to give the number per 200 g of dry soil. Before analysis, all data were transformed to $\log_{10}$ (x+1) to allow for samples where individual weed species were not present. Least significant ratios given in Tables 1 and 2 were obtained from analysis of variance, and serve only as an approximate guide to the significance of differences.

RESULTS AND DISCUSSION

Weed seed distribution

Weed seed enumeration of samples taken before cultivation showed no significant differences across the trial area. Sixteen species of potentially viable seed were recorded in quantities ranging from 1 to 146/200 g dry soil for individual weed species. The main species included chickweed (*Stellaria media*), annual mouse-ear chickweed (*Cerastium glomeratum*), redroot (*Amaranthus powellii*), fathen (*Chenopodium album*), willow weed (*Polygonum persicaria*), thorn apple (*Daturxa stramonium*), summer grass (*Digitaria sanguinalis*), smooth witchgrass (*Panicum dichotomiflorum*) and annual poa (*Poa annua*). In contrast to previous surveys of maize fields (Rahman *et al.* 1997; 1998) only a small number of white clover (*Trifolium repens*) and toadrush (*Juncus bufonius*) seed were found at this site.

Seed numbers in samples collected after the cultivation treatments are summarised in Table 1 and show the distribution of seeds in the soil profile from different implements. Samples from undisturbed plots show a significant decline with depth. This decline had the effect of roughly halving the number of seed with every 5 cm increase in depth, except between 5-10 and 10-15 cm depths which was probably an artefact of the long history of cultivation to about 15 cm depth. This trend was similar for most weed species and confirms the results of earlier studies in maize fields (Rahman *et al.* 1999). Surprisingly, cultivation with power harrow or rotary hoe did not significantly change the weed seed distribution, suggesting that despite mixing the soil in different patterns, neither implement re-distributed the seeds uniformly through the tillage depth. Ploughing was the only implement that clearly shifted the seeds to deeper profile. In ploughed plots there was a more even distribution of seeds in the top three profiles and the deepest layer of 15 – 20 cm had significantly more seeds than the other three treatments (Table 1). Moss (1988) also reported movement of seeds to deeper layers by ploughing than by tine cultivation and Feldman *et al.* (1997) found no difference in density or composition of seedbank at 0–5 cm and 5–10 cm depth in ploughed areas whereas no tillage had a more dense seedbank in the upper part of the soil profile.

TABLE 1: Distribution of weed seeds (total no./200 g dry soil) in the soil profile after cultivation treatments. Figures in brackets are percentages of total seed numbers.

Depth (cm)	Cultivation method							
	Power harrow		Rotary hoe		Plough		Undisturbed	
0-5	157	(50)	133	(52)	57	(27)	113	(53)
5-10	91	(29)	75	(30)	78	(37)	53	(25)
10-15	55	(17)	41	(16)	50	(24)	39	(18)
15-20	13	(4)	5	(2)	24	(11)	8	(4)

Least significant ratio (LSR) between any two numbers = 1.5

Weed seedling emergence

Weed seedling emergence counts in field plots recorded 18 species in numbers ranging from 1 to 433/0.1 m^2 for individual species. Of the total species, seeds of four weeds recorded in the field were not found in samples sent to the laboratory, but their numbers were very small. This again shows the good correlation between species composition of both the seedbank determined in the laboratory and the seedling populations that emerge, as demonstrated in our earlier work (Rahman *et al.* 1998).

The weed species encountered during the three counts in the field plots have been divided into four groups which are listed along with total seed numbers in Table 2. The winter broadleaf group consisted principally of chickweed, scrambling speedwell (*Veronica persica*) and annual mouse-ear chickweed, while annual poa was the only major species in the winter grass group. The summer broadleaf group comprised mainly fathen, willow weed, redroot and thorn apple. The last group, the summer grasses, included smooth witchgrass, summer grass and barnyard grass (*Echinochloa crus-galli*).

The total number of weeds for the three emergence counts is summarised at the bottom of Table 2. The overall totals show that plots cultivated with the plough had significantly fewer weeds than the undisturbed or other cultivation treatments. These differences were due to lower numbers of both summer grass and summer broadleaf weeds. The second lowest total number was recorded in the undisturbed compared to the rotary hoe or power harrow treatments. Grass weeds emerged in similar numbers in rotary hoe, power harrow and undisturbed treatments. Winter weeds emerged in too few numbers in all plots to show any clear pattern.

TABLE 2: Weed seedling emergence (no./0.1 m^2) at three, six and nine weeks after cultivation.

Cultivation method	Winter broadleaf	Winter grass	Summer broadleaf	Summer grass	All weeds
First emergence count (3 weeks after cultivation)					
Power harrow	10	2	224	140	394
Rotary hoe	10	2	172	103	297
Plough	5	2	43	37	94
Undisturbed	2	2	20	101	146
LSR	1.8	1.5	1.9	1.8	1.7
Second emergence count (6 weeks after cultivation)					
Power harrow	3	2	12	28	44
Rotary hoe	6	3	17	28	56
Plough	5	3	3	17	28
Undisturbed	1	2	42	37	95
LSR	1.7	1.7	1.7	1.6	1.4
Third emergence count (9 weeks after cultivation)					
Power harrow	2	1	8	16	25
Rotary hoe	1	2	11	20	32
Plough	2	2	5	9	17
Undisturbed	2	1	28	24	56
LSR	1.6	1.4	1.7	1.4	1.4
Total of all three emergence counts					
Power harrow	13	3	249	186	471
Rotary hoe	16	5	203	152	390
Plough	12	4	53	66	141
Undisturbed	3	3	100	168	315
LSR	1.7	1.7	1.7	1.6	1.5

An assessment of weed seedling numbers for the three individual counts (Table 2) shows that the largest proportion of all weeds emerged in the first three weeks after treatment, with numbers decreasing in each successive count. Ploughing resulted in significantly less weeds than rotary hoeing or harrowing in each emergence count. The undisturbed plots had significantly less weeds than power harrowed or rotary hoed plots in the first count but significantly more in both second and third counts, indicating a clear time shift or delayed emergence of weeds in undisturbed soil. This was principally due to very low number of broadleaf weeds that emerged in the undisturbed plots during the first three weeks. This species shift indicates that in no tillage systems summer grasses are likely to be a bigger problem than broadleaf weeds because they will emerge earlier and start competing with the crop.

From the data presented in Tables 1 and 2 we have calculated the percentage of buried weed seed found in the top 5 cm that emerged in different treatments (Table 3). This further highlights the two points discussed above. Firstly, the ploughed and the undisturbed plots had lower percentages of seeds that germinated, resulting in a lower overall density of weeds than the harrowed or rotary hoed plots. Secondly, fewer seeds germinated initially in the undisturbed plots, so that weed emergence was lower at first, but higher in the subsequent weeks. In a long term study Feldman *et al.* (1997; 1998) also found that a wheat crop grown after mouldboard ploughing had smaller seedbanks as well as fewer seedlings and there was no difference in seed numbers between 0-5 and 5-10 cm depths. In comparison, no tillage treatments had a larger seedbank and more weed seedlings, especially in the upper 5 cm of the soil profile. Another important point to note in Table 3 is that the total proportion of seed that

emerged as seedlings ranged only between 13-16% of the seed found in the 0-5 cm depth. The small differences in the percent emergence from the different treatments suggests that cultivation method may not be a significant factor in prediction models.

TABLE 3: Percentage of buried seed found in the top 5 cm soil that emerged as seedlings, calculated from data in Tables 1 and 2.

	Time after cultivation			
Cultivation method	3 weeks	6 weeks	9 weeks	Total
Power harrow	13.7	1.5	0.9	16.1
Rotary hoe	12.0	2.1	1.3	15.4
Plough	9.7	2.6	1.5	13.8
Undisturbed	6.5	5.0	2.2	13.7

The results of this study have provided useful information on timing, density and composition of weed populations that are likely to emerge under no tillage and in areas cultivated with different types of tillage implements in relation to the seedbank. Data on weed seed distribution show that soil samples for estimation of seedbank must be collected after cultivation if a field is to be ploughed because ploughing shifts significant number of seeds to deeper profiles. Rotary hoeing or power harrows, however, did not re-distribute the weed seeds to the same extent. The results presented here, along with our previous work, will help in planning effective and reliable seedbank sampling techniques and assist in predicting future weed populations.

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