SPATIAL VARIABILITY OF FATHEN SEEDS IN THE SOIL UNDER REPEAT MAIZE CROPPING

A. RAHMAN¹, T.K. JAMES¹, N. GRBAVAC²,
J.E. WALLER¹ and J. MELLOP¹

¹AgResearch, Ruakura Research Centre, Private Bag 3123, Hamilton

²AgriQuality, Batchelar Agricultural Centre, P.O. Box 609, Palmerston North

ABSTRACT

Variability in distribution of fathen seeds in the soil was investigated to develop sampling protocols. Vertical distribution of seeds was assessed at 0-2.5, 2.5-5.0, 5.0-10.0 and 10.0-15.0 cm depth. Horizontal distribution of seeds in the top 5 cm of soil was assessed in a 20 by 2.5 m grid at 50 cm intervals. Seeds were extracted from the samples by sieving and their viability was assessed. The fathen seed numbers halved with each 5 cm increase in depth. Seed numbers declined along the row in some cases but there was little localised clumping (± 1 m) of the seed. The most efficient method of sampling the fathen seedbank in a large field would be to take samples on a rectangular grid pattern to a depth of 10 cm.

Keywords: weed seed, *Chenopodium album*, fathen, seedbank, spatial diversity.

INTRODUCTION

A major factor affecting annual weed population stability is the large and potentially transient seedbank (Forcella 1993). Knowledge of the total number of weed seeds and their distribution in the soil is useful in predicting which species are likely to emerge in a particular field. This may be a good starting point for an integrated weed management programme (Cardina and Sparrow 1996; Forcella *et al.* 1993). Unfortunately their small size and location in the soil makes estimation of seed density difficult. To address this problem, many studies have been conducted during recent years to optimise soil seedbank sampling for collecting information on seed abundance and distribution (Dessaint *et al.* 1996; Rahman *et al.* 1997).

The distribution of weeds within fields is 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 move seeds to different depths in the soil (Rew and Cussans 1997). Weed seedling emergence and seedbank depletion are greater from seeds near the soil surface (James *et al.* 1998; Mulugeta and Stoltenberg 1997) because more seeds encounter conditions favourable for germination. The spatial pattern of seeds in soil influences weed population dynamics, the degree of inter- and intra- species competition, the level of outcrossing or inbreeding and the susceptibility of weed seedlings to insect pests and plant pathogens (Wilson 1992).

A better understanding of the weed seed distribution in New Zealand soils will help in the development of reliable sampling methods for weed seeds in the soil. Such methods must be reliable, easily managed and rapid, using few resources. Fathen (*Chenopodium album*) is a common weed of maize fields (Barberi *et al.* 1998; Rahman *et al.* 1998), has a medium size seed (1.0–1.5 mm), and is representative of many weed seeds. This research was conducted to study the variability of fathen seed distribution in a field under continuous maize cropping.

MATERIALS AND METHODS

This work was conducted at the Waikato Research Orchard near Hamilton between cultivation and planting in October, 1998. The soil was a Te Kowhai silt loam

(44% sand, 22% silt, 34% clay, 3.0% organic carbon and pH 5.8) and had been under continuous maize cropping for 11 years. In 1998 the site was ripped to a depth of 25 cm and then power harrowed to 10 cm prior to planting. The power harrow cultivates the soil in a horizontal circular motion and does not invert the soil as ploughing does or mix it vertically in the manner of a rotary hoe. In previous years the site was usually ploughed (to 15 - 20 cm) before power harrowing and planting. The site remained fallow and usually undisturbed each winter.

Soil sampling

To study the vertical variability, 12 intact soil samples, each 75 mm diameter, were collected to 15 cm depth at 20 m spacing along two diagonal 100 m transects. The 12 samples were then divided into 0-2.5, 2.5-5.0, 5.0-10.0 and 10.0-15.0 cm fractions and separately placed into plastic bags.

For investigations of horizontal variability, 246 samples (75 mm diameter) were taken to 5 cm depth on a grid pattern at 50 cm centres. The grid was 20 m by 2.5 m with the greater length being in the same direction as both cultivation and planting. All soil samples were placed into separate plastic bags and returned to the laboratory for processing.

Seed enumeration

On return to the laboratory, the soil samples were immediately oven dried at 60°C for 12 hours, passed through a 4 mm sieve to remove the trash material and weighed. The samples were sent to the N.Z. National Seed Laboratory, Palmerston North, for extraction and quantification of the fathen seed 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. Empty seed would indicate the loss of seed through germination or predation at different depths. Viability of the whole seeds was determined by crushing, with only those seeds exhibiting white healthy endosperm counted as viable.

Data analysis

All seed counts were adjusted to give a number per 200 g of dry soil. Before analysis, all data were $\log_{10}$ transformed after adding 1 to allow for transformation of samples with no fathen. Standard analysis of variance was inappropriate. Least significant differences given in Table 1 were obtained from analysis of variance, but serve only as an approximate guide. Trends down the soil profile were investigated by taking linear and quadratic contrasts among the depths for each core and analysing these. The trends discussed in the text, and the levels of significance, are taken from the fitting of polynomials.

For the horizontal variability, data along each row were treated separately in the analysis. A quadratic polynomial was fitted to the data to account for the overall trend. A non-linear trend along a row was considered to be an indication for aggregation of the seed on the scale of the trial (20 m) i.e. macro-clumping. Whether the fit of this model was significant or not, the data for each row were adjusted to remove any overall trend. The deviations about this line were then investigated by fitting smoothing splines using the Bayesian spline fitting programme Flexi (Upsdell 1994). A non-linear spline fit would indicate seed aggregation in a localised area (± 1 m) i.e. micro-clumping.

RESULTS

Vertical variability

The mean fathen seed numbers for the various depths are presented in Table 1. These show a linear decline with depth on the transformed scale ($P < 0.01$). This decline had the effect of halving the number of seed approximately every 5 cm increase in depth. This trend was the same for the three categories of seed counted, viable, non viable and empty. As the ratio of empty to viable seeds was similar at different depths, it appears that the distribution had not been affected by germination or predation. Furthermore, the decline with depth (Table 1) showed that the recent cultivation by power harrows had not redistributed the seeds uniformly through the tillage depth (10 cm).

TABLE 1: Mean number of fathen seeds per 200 g dry soil found at different depths in a field with repeat maize cropping.

Depth (cm)	Viable		Non-viable		Empty	
	Raw	Transformed ¹	Raw	Transformed ¹	Raw	Transformed ¹
0 – 2.5	33.9	1.23	18.2	1.13	36.9	1.40
2.5 – 5.0	22.4	1.09	17.1	1.01	33.4	1.08
5.0 – 10.0	12.9	0.76	7.1	0.74	17.4	1.06
10.0 – 15.0	6.3	0.64	4.0	0.61	9.6	0.90
LSD(5%)		0.28		0.26		0.26

¹Log₁₀(n+1)**Horizontal variability**

The horizontal variability in the numbers of viable fathen seed is presented in Fig. 1. Seed numbers tended to decline along rows 1 to 3 but this trend was not apparent in rows 4 to 6. The declines in rows 1 and 2 fitted a quadratic trend ($P<0.01$) while the trend in row 3 was linear ($P<0.01$). Non-viable seeds occurred in similar numbers to the viable (data not presented) and their numbers declined linearly in rows 1 to 4 ($P<0.05$) but not in rows 5 and 6.

FIGURE 1: Viable fathen seed numbers per 200 g dry soil to 5 cm depth in each of six rows in a field under repeat maize cropping.

Numbers of viable seeds, after removal of the overall trend, are presented in Fig. 2. Rows 1, 2 and 4 contained a great range of seed counts but sampling every 0.5 m showed no evidence of micro-clumping of seed that might be associated with the seed fall from either a large fathen plant or a small clump of plants. Although rows 3 and 5 showed some indication of localised clumping of seed, the only significant clumping occurred in row 6 (Fig. 2).

FIGURE 2: Data from Fig. 1 with the overall linear or quadratic trends removed to show the variability of seed distribution. The dotted lines represent 95% pointwise confidence intervals.

DISCUSSION AND CONCLUSION

Normal agricultural management systems such as tillage and cultivation facilitate the incorporation of weed seeds into the soil within the tillage depth. This is true of total weed seed populations and those of individual species across different cropping and weed management systems (Zhang *et al.* 1998). It has been shown that the weed flora emerging within 1-2 months after planting a crop could be predicted using the active or non-dormant fraction of the soil seedbank (Forcella *et al.* 1993; Rahman *et al.* 1998). In a study by Zhang *et al.* (1998), the active soil seedbank was found to be closely related to the 0-7.5 cm sampling depth for the small-seeded species while for relatively large-seeded species, the relationship held with a sampling depth up to 15 cm below the soil surface.

The depth from which soil samples for weed seedbank estimation are collected is important because burial depth significantly affects seed germination in most species (Forecella 1993; Mulugeta and Stoltenberg 1997). Although seeds may germinate from relatively deep in the soil, Zhang *et al.* (1998) found that most seedlings emerge from the top 8 cm. Including the dormant seedbank from greater soil depths did not provide reliable estimations of the above-ground weed populations in previous studies (Cardina and Sparrow 1996; Forcella 1993). Our results (Table 1) also suggest that in the case of fathen (and possibly other medium to large-seeded species), a sampling depth of 10 cm may account for over 90 percent of the total seedbank and that this may be more closely related to the active soil seedbank referred to by Zhang *et al.* (1998).

Primary seed dissemination from arable weed species with no specialised dissemination structure is generally limited, with most seeds falling within a short distance of their source. The close canopy provided by a maize crop restricts wind movements more than in surrounding field margins or open land, further reducing dispersal distances (Rew *et al.* 1996). Similarly, secondary movement of seeds by cultivators is also small in real farm situations. The majority of average to large size weed seeds (>1 mm) would be moved less than 1 m with different cultivation equipment (Rew and Cussans 1997). Therefore we could expect patches of weeds like fathen to retain their position within the field.

Results from our study showed some evidence of macro-clumping (± 20 m) (Fig. 1) but little evidence of micro-clumping (± 1 m) (Fig. 2). The latter indicated that a sample is unlikely to be biased by finding a small clump of seed during random sampling. However, the macro-clumping indicated that a structured sampling pattern should be used when sampling a large field. It can be concluded from these results that a rectangular grid pattern would give equal weight to all areas sampled and be less influenced by macro-clumping than a diagonal transect pattern.

Reliable estimates of the level of weed infestation in different fields and within fields, could help in planning appropriate weed management programmes. Regular annual sampling could also track the effectiveness of the programmes, and possibly lead to reduced herbicide use. Good correlations between species composition of the seedbank and above ground weed populations have been demonstrated in our earlier work (Rahman *et al.* 1998). Adequate seedbank sampling techniques would allow good predictions of future weed populations. The results presented here, along with previous results, will help in the development of cheap, effective and precise seedbank sampling techniques.

ACKNOWLEDGEMENTS

This research was funded by the New Zealand Foundation for Research, Science and Technology. We thank the staff of the N.Z. National Seed Laboratory for enumeration of weed seedbank in field samples.

REFERENCES

- Barberi, P., Cozzani, A., Macchia, M. and Bonari, E., 1998. Size and composition of the weed seedbank under different management systems for continuous maize cropping. *Weed Res.* 38: 319-334.
- Cardina, J. and Sparrow, D.H., 1996. A comparison of methods to predict weed seedling populations from the soil seedbank. *Weed Sci.* 44: 46-51.
- Dessaint, F., Barralis, G., Caixinhas, M.L., Mayor, J.P., Recasens, J. and Zanin, G., 1996. Precision of soil seedbank sampling: how many soil cores? *Weed Res.* 36: 143-151.
- Forcella, F., 1993. Prediction of weed densities from the soil seed reservoir. *Proc. Int. Symp. Indian Soc. Weed Sci. Hissar*, Nov. 1993, 1: 53-56.
- Forcella, F., Eradat-Oskui, K. and Wagner, S.W., 1993. Application of weed seedbank ecology to low-input crop management. *Ecological Applications* 3: 74-83.
- James, T.K., Rahman, A., Wardle, D.A. and Bonner, K.I., 1998. Survival of nodding thistle (*Carduus nutans*) seed buried at different depths in four soils. *Proc. 51st N.Z. Plant Prot. Conf.*: 33-37.
- Mulugeta, D. and Stoltzenberg, D.E., 1997. Increased weed emergence and seedbank depletion by soil disturbance in a no-tillage system. *Weed Sci. US*: 234 – 241.
- Rahman, A., James, T.K., Waller, J.E. and Grbavac, N., 1997. Soil sampling studies for estimation of weed seedbanks. *Proc. 50th N.Z. Plant Prot. Conf.*: 447-452.
- Rahman, A., James, T.K., Bourdôt, G. and Grbavac, N., 1998. Weed seedbank estimation, spatial distribution, decline and potential for predicting future weed populations. *Plant Prot. Quart.* 13(3):117-122.
- Rew, L.J. and Cussans, 1997. Horizontal movement of seeds following tine and plough cultivation: implications for spatial dynamics of weed infestations. *Weed Res.* 37: 247-256.
- Rew, L.J., Cussans, G.W., Muggleston, M.A. and Miller, P.C.H., 1996. A technique for mapping the spatial distribution of *Elymus repens* L. with estimates of the potential reduction in herbicide usage from patch spraying. *Weed Res.* 36: 283 – 292.
- Upsdell, M.P., 1994. Bayesian smoothers as an extension of non-linear regression. *The N.Z. Statistician* 29(2): 66-81.
- Wilson, M.F., 1992. The ecology of seed dispersal. Pp 61-85. *In: Seeds: The Ecology of Regeneration in Plant Communities*, M. Fenner (ed.); C.A.B., Wallingford, U.K.
- Zhang, J., Hamill, A.S., Gardiner, I.O. and Weaver, S.E., 1998. Dependence of weed flora on the active soil seedbank. *Weed Res.* 38: 143-152.