PREDICTING BROADLEAF WEED POPULATIONS IN MAIZE FROM THE SOIL SEEDBANK

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ABSTRACT

Investigations over three years studied the relationship between weed seeds in the soil seedbank and the resultant populations of broadleaf weeds in maize fields. Plots were protected from pre-emergence herbicide, after which soil samples (100 mm) were collected and weed seeds therein enumerated. Emerged weed seedlings in field plots were counted over the following 8 weeks. Up to 67 broadleaf weed species were identified, although not all were found at every site and some were specific to a region or soil type. On average 2.1–8.2% of the seed in the soil seedbank emerged. For most weeds strong linear relationships were noted between seedling numbers and the seed numbers in the soil, although for some, like white clover (*Trifolium repens*), only a weak relationship was observed. In the case of fathen (*Chenopodium album*), which had the largest seedbank, there was evidence of asymptotic behaviour with seedling emergence levelling off at high seed numbers.

Keywords: weed seedbank, weed emergence, broadleaf weeds, arable weeds, seedbank enumeration.

INTRODUCTION

Annual weed populations establish every year from persistent seedbanks in the soil. As most of the weed species in arable cropping systems are annuals, some knowledge of the seedbank would be a good starting point for an integrated weed management programme (Forcella 1993; Cardina & Sparrow 1996). An estimate of the seedbank population in the soil combined with the knowledge of germination and behaviour of specific weed species offers considerable potential for predicting future weed infestations (King et al. 1986; Grundy 2003). Some bioeconomic weed management models now use seedbank estimates to predict weed population dynamics and competitiveness (Lybecker et al. 1991).

The likely density and composition of a weed infestation arising after cultivation would in most cases be determined by the soil weed seedbank and the proportion of seed of particular species likely to emerge as seedlings (Roberts & Ricketts 1979). However, estimating the size of the seedbank of arable weeds and predicting the emergence of different weed species is often very difficult (Forcella et al. 1992). Previous studies have concentrated on seedbank estimation methods and optimising the soil seedbank sampling procedures for arable soils (Rahman et al. 2001).

The present field study conducted over a three-year period was designed to establish the relationship between laboratory enumeration of the soil seedbank and field populations of various weed species. The results for grass weeds were reported recently (Rahman et al. 2003). This paper presents and discusses the data for some common broadleaf weeds found in these maize crops.

MATERIALS AND METHODS

This 3-year field study was conducted at several sites between 1999 and 2002 in the major maize growing regions, Waikato (20 sites), Bay of Plenty (four sites) and Poverty Bay (six sites). Details of the methods are similar to those outlined in Rahman et al.

(2003) and are reported here only in brief. For this study a site refers to a single maize field and some properties had more than one site.

In September/October, immediately before the application of pre-emergence herbicides at each site, six plots of 1 m^2 each were protected from the herbicide by covering with a sheet of black polythene. The sheet was removed soon after the spraying operation and a quadrat of 0.1 m^2 was clearly marked in the centre of each plot. Soil samples for weed seed enumeration were then collected by taking 10 cores of 25 mm diameter to a depth of 100 mm from the immediate surroundings of each quadrat. Individual plot samples were thoroughly mixed in the laboratory and immediately oven dried at 65°C for 24 h to arrest seed germination. A subsample of 500 g dry weight was then sent to the Seed Testing Station in Palmerston North for seed extraction and quantification by washing and dry sieving as described by Rahman et al. (2001). Seed viability was determined by 'destructive crushing' in which seeds containing undecayed endosperm were recorded as potentially viable.

In the field, at about 4 and 8 weeks after soil sampling, weed seedlings that had emerged in each 0.1 m^2 quadrat were identified, counted and then removed. It has been shown that most weed seedlings that emerge later than 8 weeks after planting are not likely to compete with the maize crop (James et al. 2000). Total seedlings that emerged in each of the 6 plots were averaged and the sites were used as replicates for statistical analyses. All the data were natural log transformed to stabilise variance, and comparisons were then made using regression analyses of seedling numbers on seeds in the soil samples.

RESULTS AND DISCUSSION

The total number of broadleaf weed species identified in the Waikato region, which had 20 of the 30 sites was 67, but not all species were found at every site. In the Poverty Bay region only 15 species were recorded, while 25 species were found in the Bay of Plenty sites. The number of weed species recorded in the field was usually slightly higher than that enumerated in the laboratory. This was probably due to the small sample size sent to the laboratory compared to the volume/area used in the field. The presence of a particular weed species at a site was strongly influenced by region. For example, purslane (*Portulaca oleracea*) and hairy buttercup (*Ranunculus sardous*) were found only at the Waikato sites; the latter restricted to peaty soils. Willow weed (*Polygonum persicaria*) was not found in Poverty Bay or South Waikato sites, docks (*Rumex* spp) were found on only one site in Poverty Bay and black nightshade (*Solanum nigrum*) was not noted at the Bay of Plenty sites. Some weeds like fathen (*Chenopodium album*), twin cress (*Coronopus didymus*) and white clover (*Trifolium repens*) were found in all regions, often in large numbers.

Figure 1 shows the number of weed seedlings emerged in the field plotted against the number of seeds found in the soil seedbank for six of the more abundant broadleaf weeds. The regression equations for these relationships and mean percentage emergence for these species are presented in Table 1. Fathen was present at 20 of the 30 sites and the seedlings that emerged as a proportion of the weed seedbank ranged from 1-21% (3-542 seedlings/m^2) with an overall average of 4.3% (119/m^2). Docks, mostly broadleaved dock (*Rumex obtusifolius*), were present at 17 of the 30 sites with a seedling emergence range of 1-14% (2-135/m^2) and an overall average of 7.7% (31/m^2). Black nightshade was present at 19 sites and exhibited a large range in the proportion of seedlings that emerged (1-75%, 2-273/m^2) with an overall average of 8.2% (55/m^2). Twincress was present in all the regions but only in 11 of the sites. Its emergence was less variable (1-10%, 2-128/m^2) with an average value of 2.1% (29/m^2). Dock, black nightshade, fathen and twincress all exhibited strong relationships between seedling numbers and the number of seeds enumerated in the soil samples (Table 1). In general, the largest variations in percent emergence were associated with low seed/seedling counts.

Willow weed was present at 14 sites in two regions in reasonably large numbers (3-202 seedlings/m^2) with an emergence range of 1-35% and an overall average of 7.9%

(41/m^2). However, despite this level of infestation it did not exhibit a strong relationship with its seedbank (Table 1). The relationship was also weak for white clover which was present at all the sites in numbers ranging from 1-157 seedlings/m^2, with an emergence range of 1-7% and an overall average of 2.2% (17/m^2). This is probably due to the fact that an unknown proportion of white clover seed is usually 'hard seed' and not likely to germinate for many years (Harris 1987).

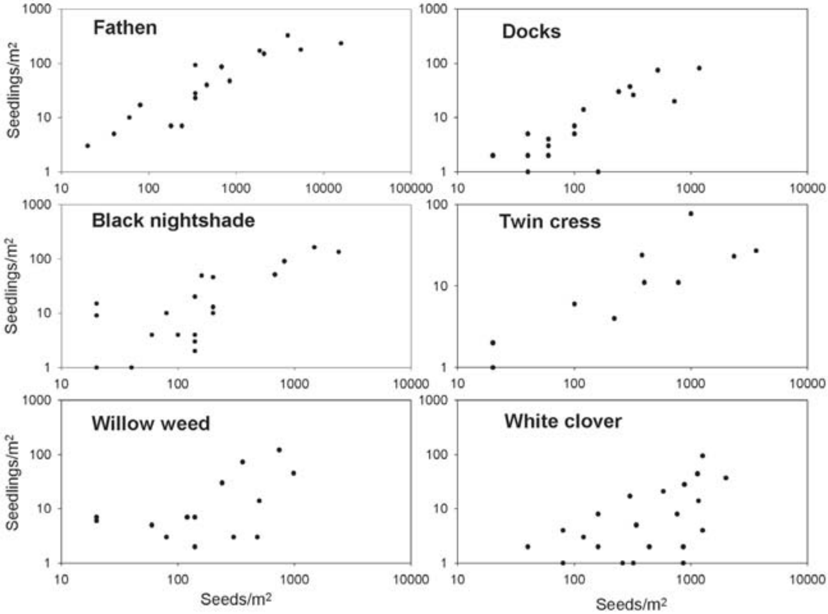

FIGURE 1: Emergence of six abundant broadleaf weeds (no. seedlings/m^2) plotted against the presence of their seed in the soil seedbank (no. seeds/m^2).

TABLE 1: Regression statistics for seedling numbers (y) relative to the soil seedbank (x) and the overall percentage of seeds that emerged.

Weed species	% of seed that emerged	Regression equation[1]	R^2	F-statistic	P-value
Fathen	4.3	$y = 20.35\sqrt{x} - 3.19\ x - 26.79$	0.89	97.10	0.000
Docks	7.7	$y = 1.01\ x - 2.69$	0.93	34.45	0.000
Black nightshade	8.2	$y = 0.97\ x - 2.27$	0.90	22.00	0.000
Twin cress	2.1	$y = 0.82\ x - 2.41$	0.83	36.09	0.000
Willow weed	7.9	$y = 0.58\ x - 0.83$	0.25	4.26	0.060
White clover	2.2	$y = 0.70\ x - 2.48$	0.30	8.11	0.010

[1]For natural log transformed data.

Some of the other broadleaf weeds recorded in large numbers but at fewer than 10 sites included: mallows (*Malva* spp) in Bay of Plenty sites; wireweed (*Polygonum aviculare*) and broad-leaved plantain (*Plantago major*) in Waikato region only; and chickweed (*Stellaria media*), annual mouse-ear chickweed (*Cerastium glomeratum*), bitter cress (*Cardamine hirsuta*), lotus (*Lotus pedunculatus*) and scarlet pimpernel (*Anagallis arvensis*) in the Waikato and Bay of Plenty sites. Spurrey (*Spergula arvensis*) was a prominent species on the heavy clay soil while pennyroyal (*Mentha pulegium*) and toad rush (*Juncus bufonius*) were plentiful in the peaty soils. At one site parsley piert (*Aphanes arvensis*) was abundant in the soil seedbank at 21,800 seeds/m^2, of which only 2 emerged as seedlings (0.008%). This is probably due to the fact that parsley piert is a winter growing species that normally germinates in autumn and winter.

The broadleaf weeds emerged in association with the grass weeds that were also present at these sites (Rahman et al. 2003). At some sites these broadleaf weeds dominated while at others grass weeds were the major component. However, the presence of grass weeds does not appear to have initially influenced the proportion of broadleaf weeds that emerged. While some species like purslane and white clover had a relatively narrow range of emergence (1-7% in both cases), others had a much larger range of emergence, e.g. 1-14% for docks, 1-21% for fathen, 1-35% for willow weed and 1-75% for black nightshade. The fate of weed seeds in the soil is determined by both internal physiological conditions and the environmental conditions encountered in the soils (Murdoch & Ellis 1992). There is likely to be a number of factors affecting seedling emergence when compared to the number of seeds in the soil, although seed size and more importantly their distribution in relation to soil depth have a major influence on seedling emergence. The spring germinating weed species with medium to large seed, such as fathen, willow weed, black nightshade and spurrey, have been reported in overseas investigations to germinate mainly from the top 20–40 mm (Chancellor 1964; du Croix Sissons et al. 2000). However, in the lighter, more friable local soils, their emergence was not constrained by soil depths up to 50 mm (James et al. 2002). As the soil samples in the present study were taken to a depth of 100 mm, then even if there were no other influences, it would be expected that only about 50% of the seed would normally emerge. This is assuming that the seed is evenly distributed through the sampled profile after cultivation. As this is unlikely (Rahman et al. 2000), it is the uneven spread of seed that probably accounts for much of the variation in emergence.

As was the case with most grass weeds identified at these sites (Rahman et al. 2003), the regression analyses of the data for most broadleaf weeds assumed a linear relationship between seed numbers and seedling emergence (Table 1). However, in complex biological systems such as the soil, this assumption is not always valid (Forcella 1993). In particular, asymptotic behaviour might be expected when soil seedbank numbers become very large as was the case with smooth witchgrass (*Panicum dichotomiflorum*) where seedling emergence appeared to level off at high seed numbers (Rahman et al. 2003). This was more obvious here for fathen (Fig. 1), which was found in the largest number of any broadleaf weed species at these sites (maximum number recorded was 26,270 seeds/m^2). As the graph for fathen shows some evidence of an asymptote, a quadratic regression equation for this species yielded the best fit (Table 1).

The overall average proportion of the active weed seedbank emerging as seedlings in the field for most broadleaf weeds was slightly lower than that found at these sites for the warm zone annual grasses (Rahman et al. 2003). The findings in general are in line with earlier observations and the overseas findings (Rahman et al. 2003; Zhang et al. 1998). However, as discussed by Rahman et al. (2003), in addition to estimating the numbers and species of weeds likely to emerge, it would be helpful to also have some knowledge of the timing and spread of the flush of weed emergence relative to environmental variables. Often the very early germinating individuals make the most significant contributions to competition and seed return. Prior information on these aspects would be valuable in predicting the likely density and diversity of weed infestation in a crop and would assist in better forward planning, management of resources and designing appropriate control regimes.

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