SEEDLING EMERGENCE IN *CHENOPODIUM ALBUM* AND THE PREDICTIVE VALUE OF SOIL SEED BANKS

G.W. BOURDÔT¹, G.A. HURRELL¹, A. RAHMAN²,
R. ABERNETHY³ and N. GRBAVAC⁴

¹AgResearch, New Zealand Pastoral Agriculture Research Institute Ltd,
P.O. Box 60, Lincoln

²AgResearch, Ruakura Agricultural Research Centre, Private Bag 3123, Ruakura

³AgResearch, Invermay Research Centre, Private Bag 50034, Invermay

⁴Seed Testing Station, P.O. Box 609, Palmerston North

SUMMARY

At three sites (Ruakura, Lincoln, Invermay) on arable land in 1990/91, 1991/92 and 1992/93, the population densities of seedlings of fathen (*Chenopodium album*) emerging on small field plots after a single soil cultivation in different months was assessed. Density of soil-borne seed of fathen was measured before each cultivation in 1992/93. Seedling emergence occurred mainly in the spring and summer at all sites but the monthly distribution of emergence varied greatly between sites and years. The maximum fraction of the seed bank expressed as seedlings also varied greatly from 18% in January at Ruakura, to 2.5% and 7.5% at Lincoln and Invermay respectively following cultivation in November. Such high between year variability in the emergence of *C. album* seedlings indicates that a simple empirical approach to forecasting seedling populations in this weed may not be possible.

Keywords: weed seed banks, seedling emergence patterns, *Chenopodium album*, forecasting weed seedling density

INTRODUCTION

The value of being able to forecast the floristic composition and density of a weed population in a crop from an estimate of the size of the soil seed population made prior to sowing the crop has been discussed by several authors. If this was possible, the selection of the most appropriate soil residual herbicide would be facilitated (Naylor 1970; Roberts and Ricketts 1979). Given adequate information on the size of the losses to be expected in different crops at a forecasted weed level (Kropff and van Laar 1993), it would also be possible to avoid sowing a crop with a high and unpreventable expected loss. It may also be possible to adjust sowing dates of crops to avoid weed emergence peaks and thus minimise yield losses from weed competition. The basic model given by Roberts and Ricketts (1979) is that the density of a weed plant population arising after a cultivation at a given time of year would be the product of the density of soil-borne seed and the proportion of these seeds expected to give rise to emerged seedlings at that time of year. From species-specific functions based on field observations that describe the annual pattern in the emerging fraction of a seed bank, Roberts and Ricketts suggested it may be possible to forecast the seedling density for a weed represented in the seed bank.

Weed species vary in the seasonal distribution of seedling emergence (eg. winter annuals cf. summer annuals) and in the fraction of their banks emerging as seedlings because of species-specific dormancy and germination characteristics. Furthermore, for a given species, the fraction of soil-borne seeds giving rise to emerged seedlings can be expected to vary from year to year and from site to site due to the effects of temperature and soil moisture and other factors that control the breaking and re-imposition of seed dormancy and germination (Egley 1986). The reliability of a weed forecast using the emergence pattern of a weed based on the average of observations

Proc. 47th N.Z. Plant Protection Conf. 1994: 1-5

over years and sites, as suggested by Roberts and Ricketts (1979), would depend largely on the magnitude of these variations.

An advantage of this "empirical" approach to forecasting the size of a particular weed population over more mechanistic approaches based on soil moisture and temperature (Alm *et al.* 1993) would be avoidance of the difficulties associated with forecasting these climate variables. The purpose of the work described in this paper was to determine the feasibility of this empirical approach to forecasting seedling emergence by examining the annual patterns of emergence in the common weed species *Chenopodium album* at three sites over 3 years.

METHODS

The experiment was conducted during 1990/91, 1991/92 and 1992/93 on arable land at three sites; Ruakura, Lincoln, Invermay. In the spring of each year six replicates (four at Lincoln) of 12 plots measuring 0.25 m² (0.2 m² at Invermay) were marked out on bare soil. These plots were located in cropping fields except at Ruakura where a volume of soil from the top 10 cm in a cropping field near the Ruakura Agriculture Centre was relocated in late winter each year to a 10 cm deep bed at the Centre to facilitate regular assessments.

For each of the 3 years and three sites, a different plot in each replicate was cultivated each month by hand to a depth of 10 cm. A sample of soil (500 g air dry) was removed from each plot for later enumeration of the soil-borne seeds. The remaining plots (except those cultivated the previous month) were treated with paraquat to prevent weeds seeding and adding to the seed banks on the plots. Four to 6 weeks after cultivation, when weed seedling emergence on the cultivated plots was considered to have stopped, the seedlings of *C. album* on these plots were counted. The seeds of *C. album* in each soil sample were removed by a wet sieving technique at the laboratory of the NZ Seed Testing Station at Palmerston North. Seeds that did not flatten under light finger pressure were declared viable and counted. Operator variation in this procedure rendered the 1990/91 and 1991/92 samples useless; only the 1992/93 samples gave reliable estimates of the density of soil-borne seeds.

All sites were on arable land and were cropped annually during the three-year experimental period, except for the small areas occupied by the experiment. At Lincoln and Invermay, where the study was conducted *in situ*, the experimental area was relocated each spring to a new part of the field. At Ruakura, the field from which the soil was taken was in continuous maize and sprayed annually with either atrazine or linuron and alachlor. At Lincoln the experimental field was sown to peas in 1990 and 1992 and treated with MCPB and to wheat treated with bromoxynil/ioxynil/mecoprop (Axall) in 1991 and 1993. At Invermay the site was originally in pasture and was planted to barley in 1991, green-feed oats in 1992 and coriander in 1993.

The seed bank data were square root transformed and the linear, quadratic and cubic components of time were fitted to determine if the soil seed density changed over the year.

For each experimental period (September to August), the seedling densities from each cultivation were normalized by dividing them by the sum total of seedlings arising from all cultivations during the experimental period. This was done to remove the effects of any differences in the size of the seedbank between the three different areas used in the 3 different years.

RESULTS

The population density of *C. album* seedlings arising after cultivation is presented in Figure 1. The normalized densities have been plotted from 1 July to 30 June to place the periods of emergence nearer the centre of the graphs. The resulting patterns of seedling emergence varied greatly between sites and between years within sites although emergence was generally restricted to the September to February period (spring and summer). At Ruakura, however, the period during which emergence occurred was longer than at Lincoln or Invermay (Fig.1).

Figure 1: Seedling emergence in *Chenopodium album* following soil cultivation in each month of the year for 1990/91, 1991/92, 1992/3 and part of 1993/94 at three sites (Ruakura, Lincoln, Invermay). The data are the population densities of seedlings following each cultivation, normalized by division by the total number of seedlings arising in each year (see text). In the figure each season is 3 months long with the first day of "spring" set to 1 September.

The density of *C. album* seeds in the soil during 1992/93, expressed as the number of viable seeds/m² to a depth of 10 cm, varied greatly between the three sites, being lowest at Ruakura and highest at Invermay (Fig.2A). At both the Ruakura and Lincoln sites, there was no evidence in the data that the densities of the seed banks changed over the year. At these two sites the seed banks were modelled with horizontal lines using the grand average seed densities of 287 and 1218 seeds/m² for Ruakura and Lincoln respectively. By contrast, at the Invermay site, the linear and quadratic effects of time were significant ($P < 0.01$ and < 0.05 respectively) and the seedbank at this site was modelled with a quadratic polynomial. The fitted seed densities at day zero (21.9.92) and day 332 (19.8.93) were 4816 and 1742 seeds/m² respectively, corresponding to a decline in the seed bank of 64% over this 11 month period.

Figure 2: Time trends in the population density of viable soil-borne seeds of *Chenopodium album* (A), and the proportion of these viable seeds expressed as emerged seedlings following cultivation (B) at three sites (Ruakura, Lincoln, Invermay). Data points are the means of six replicate samples (four at Lincoln). In (A) curves fitted are the overall means for Ruakura and Lincoln (287 and 1218 seeds/m² respectively) and the quadratic polynomial ($Y=69.4-0.221t+0.000412t^2$) for Invermay where Y is the square root of seed density to 10 cm depth and t is time in days after 21 September 1992.

The densities of *C. album* seedlings arising in 1992/93 after each cultivation expressed as a proportion of the modelled soil-borne seed densities at the time of cultivation varied between sites (Fig.2B). The highest emergence occurred at the Ruakura site (18% of the seed bank in late January 1993) and similarly high levels of emergence were exhibited following cultivation in September through until January at this site. By contrast at Lincoln a maximum of 2.5% of the seedbank emerged with cultivation in early December while at Invermay a maximum of 7.5% of the seedbank gave rise to seedlings following cultivation in late November.

DISCUSSION

The purpose of this work was to determine if the emergence of *C. album* seeds as seedlings could be reliably forecast by multiplying a species-specific emergence function (giving the proportion of the seed bank emerging following cultivation at different times of the year) by the size of the seed bank at a time before crop seed bed preparation. Given a reliable estimate of the density of soil-borne seed, the reliability of such a forecast would depend on the level of between year and between site variability in the temporal distribution of seedling emergence and on the adequacy of this simple multiplicative model.

The density of seedlings arising after cultivation of the soil in different months of the year did not follow a "smooth" pattern (Fig. 1). It also varied greatly between the three years and sites indicating that even had the data been amenable to description by a simple smoothing function, the same function could not accurately describe the pattern of seedling emergence in different years and at different sites. This also means

that the proportion of the bank expressed as seedlings will be equally unsuitably modelled in this way. Another difficulty is that the proportion of the seedbank of *C. album* expressed as seedlings varied greatly between sites. Taken together these results indicate that the seedling density of *C. album* could not be reliably forecast as the product of soil seed density and a function describing the monthly pattern in the emerging fraction of the *C. album* seed bank. It appears that a more complex approach will be needed to achieve this goal, that takes into account the effects of environmental variables on the germination and emergence processes (Alm *et al.* 1993).

An interesting feature of the soil seed bank at Invermay was that it declined significantly (64%) during the 1992/93 growing season (Fig.2A), despite remaining undisturbed by cultivation during this period. Such high annual rates of loss of soil-borne weed seeds are generally characteristic of frequently disturbed soil; lower rates of loss are usually found on undisturbed soil (Roberts and Feast 1973; Roberts and Dawkins 1967). In a study of 17 annual weed species, Barralis *et al.* (1988) categorized *C. album* as a species with a low annual rate of seed decrease (about 40% per year) under cultivated conditions. Roberts and Dawkins (1967) found that viable *C. album* seeds disappeared from the seed bank in an arable soil at a rate of 28% per year when the soil was cultivated either twice or four times per year. Germination must account for some loss in the *C. album* seed bank at Invermay. Since a maximum of 7.5% of this bank was expressed as seedlings, germination cannot be primarily responsible unless a very high level of unsuccessful germination occurred. We cannot explain the high rate of loss at Invermay. If this unexpectedly high rate of seed loss is a real feature of some *C. album* seed banks, then it would have to be accounted for in any model that attempts to forecast seedling emergence density from seedbank size.

ACKNOWLEDGEMENTS

We thank Dave Saville for helpful advice during the planning of the experimental programme and for assistance with data analysis.

REFERENCES

- Alm, D.M., Stoller, E.W. and Wax, L.M., 1993. An index model for predicting seed germination and emergence. *Weed Tech.* 7: 560-569.
- Ball, D.A. and Miller, S.D., 1989. A comparison of techniques for estimation of arable soil seedbanks and their relationship to weed flora. *Weed Res.* 29: 365-373.
- Barralis, G., Chadoeuf, R. and Lonchamp, J.P., 1988. Longevity of annual weed seeds in a cultivated soil. *Weed Res.* 28: 407-418.
- Benech Arnold, R.L., Ghersa, C.M., Sanchez, R.A. and Insausti, P., 1990. A mathematical model to predict *Sorghum halepense* (L.) Pers. seedling emergence in relation to soil temperature. *Weed Res.* 30: 91-99.
- Egley, G.H., 1986. Stimulation of weed seed germination in soil. *Rev. Weed Sci.* 2: 67-89.
- Forcella, F., 1992. Prediction of weed seedling densities from buried seed reserves. *Weed Res.* 32: 29-38.
- Kropff, M.J. and van Laar, H.H., 1993. Modelling Crop-Weed Interactions. CAB International, Great Britain.
- Naylor, R.E.L., 1970. The prediction of blackgrass infestations. *Weed Res.* 10: 296-299.
- Roberts, H.A. and Dawkins, P.A., 1967. Effect of cultivation on the numbers of viable weed seeds in soil. *Weed Res.* 7: 290-301.
- Roberts, H.A. and Feast, P.M., 1973. Changes in the numbers of viable weed seeds in soil under different regimes. *Weed Res.* 13: 298-303.
- Roberts, H.A. and Ricketts, M.E., 1979. Quantitative relationships between the weed flora after cultivation and the seed population in the soil. *Weed Res.* 19: 269-275.
- Wilson, R.G., Kerr, E.D. and Nelson, L.A., 1985. Potential for using weed seed content in the soil to predict future weed problems. *Weed Sci.* 33: 171-175.