SURVIVAL OF NODDING THISTLE (*CARDUUS NUTANS*) SEED BURIED AT DIFFERENT DEPTHS IN FOUR SOILS

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ABSTRACT

The viability of nodding thistle (*Carduus nutans*) seed buried at three depths in four different soils was evaluated over a 16 year period. Seed viability was affected more by burial depth than by soil type. The amount of viable seed retrieved from the top 2 cm soil layer after 1 year was less than 16% of that buried, while up to 71% and 84% of seed buried at the 5 cm and 20 cm depths respectively remained viable. Sixteen years after burial, up to 20% and 32% viable seed was retrieved from the 5 and 20 cm depths respectively. It is estimated that if left undisturbed, it would take between 14 to 80 years for viable seed numbers to be reduced to 1% of the original seed numbers, depending on soil type.

Keywords: Buried seed, weed seed, seed longevity, nodding thistle, *Carduus nutans*.

INTRODUCTION

Annual and biennial broadleaf weeds are a severe problem on many pastoral farms in New Zealand, partly because of the persistence of viable weed seed in the soil. Seeds allow plants to effectively escape seasonal periods of unfavourable climatic conditions, to locate new sites for colonisation and to increase the size of the population (Buhler *et al.* 1998). Even among perennial plants with the capacity for clonal growth, seed reproduction could be an important source of dispersal and regeneration especially from small founder populations. Propagation by this mechanism needs to be examined and allowed for when formulating effective weed management strategies (Popay and Thompson 1979; Forcella 1992).

The aspect of seed ecology most relevant to weed control is germination behaviour, i.e., the timing and pattern of germination and longevity of viable seed in the soil system. Because of differences in germination behaviour between species, some species produce a more persistent soil seed bank than others (Thompson and Grime 1979). These differences can appreciably affect the efficacy of all weed control measures.

For most weed species, the main factors affecting seed germination are moisture and the amount and quality of intercepted light (Medd and Lovett 1977). Seed which is viable but does not germinate because of enforced, induced or innate dormancy is subject to ageing processes, fungal parasitism and faunal predation etc. (Buhler *et al.* 1998), which combine to reduce the proportion of viable seed. The primary factor affecting seed longevity is the depth to which seed is buried because of the differences in soil moisture, aeration, light availability and temperature within the soil profiles (Popay and Thompson 1979; Roberts and Feast 1972). Since these factors are affected by variables such as soil type (Forcella 1992), it is important that longevity experiments are conducted in a range of soils. This paper reports on the results of an experiment conducted at four field sites with varying soil characteristics aimed at evaluating the effect of burial depth on the viability of nodding thistle (*Carduus nutans*) seed.

MATERIALS AND METHODS

Four soil types were selected as representative of the main soils of the Waikato region (Table 1). In June 1981, 90 sets of 200 (0.44 g) freshly gathered nodding thistle seed were each mixed with heat sterilised soil (60 g) collected from each site. For each site, 30 tubes (25 cm length of perforated, 6 cm diameter drainpipe) were each filled with non-sterilised soil from that site. During this process, two seed/soil mixtures were placed in fine nylon mesh bags (0.25 mm) for each tube and placed at 5 cm and 20 cm from the top end of the pipe, situated within the soil used to fill the tube. The top 2 cm of the pipe was left free of soil and the third batch of seed/soil mix was placed there, separated from the soil below by a layer of fine nylon mesh but uncovered at the top. These pipe sections were then buried vertically with their tops flush with the soil surface in a regular 10 x 3 matrix at 20 cm centres. The burial sites were in permanent pasture that was regularly grazed or mown.

TABLE 1: Descriptions and some characteristics of the soils used for this study.

Soil	% sand	% clay	% OC ¹	pH	CEC ² meq/100g	Field capacity %
Horotiu sandy loam	61	15	8.7	5.4	37.4	44.8
Dunmore silt loam	54	17	19.5	5.5	51.7	66.7
Rukuhia peat	24	16	49.1	4.6	103.6	60.7
Hamilton clay loam	29	31	4.6	5.6	28.2	36.8

¹OC = Organic carbon; ²CEC = Cation exchange capacity.

At 2 - 4 monthly intervals for the first 3 years after burial, emerged seedlings were counted and removed from the tops of the pipe sections. After 1, 2, 3, 5, 11 and 16 years, 3 randomly selected pipe sections were retrieved from each site in June or July and the viable seed from each depth counted. Seed viability was determined by germination in an unheated glasshouse. The contents of each nylon bag or the 0 - 2 cm layer were spread thinly on paper towels laid over damp vermiculite. At approximately monthly intervals, the emerged nodding thistle seedlings were counted and removed and the soil stirred. This procedure was repeated until no further seedlings emerged (4 - 6 months).

RESULTS AND DISCUSSION

The viability of the original seed (collected in autumn 1981) as determined by the Official Seed Testing Station, Palmerston North was 81.5%. This value has been used for calculating the initial number of viable seeds (163) buried at each depth.

Results from the four sites show that seed viability was affected primarily by burial depth and secondly by soil type. The viability of nodding thistle seed buried in the top 2 cm of the soil declined rapidly, with only 1 - 16% of the original viable seed germinating when retrieved after 1 year and with no viable seed being present in any of the soils in year 16 (Figure 1). Although some of the seed in the top layer germinated in the field, this accounted for only 3 - 7 % of the viable seed in the first year and a similar proportion in the second year. No seed germinated in the field during the third year. More than 80% of the viable seed in the top 2 cm remained unaccounted for, which suggests that, under normal field conditions, much of the seed that falls to the ground is lost within the first year unless it is quickly buried.

At greater depths some nodding thistle seed remained viable for the duration of the study. Data presented in Figure 2 show that between 37 - 71 % and 64 - 84% of the seed were still viable after 1 year at the 5 and 20 cm depths respectively. After 16 years this had fallen to 0 - 20% and 1 - 32% for the two depths respectively. In a similar study that lasted four years Popay and Thompson (1979) also found that seed in the top layer disappeared in 3 - 4 years but when buried at 5 cm depth, they predicted that it would take 8 - 9 years to largely disappear. For this prediction they used a constant rate of decay method. When their data were fitted to the exponential decay rate method, their

FIGURE 1: Percentage of viable nodding thistle seed buried at three depths in soil (average of four soil types).

results predict 28 - 161 years of viability, which is closer to our prediction (Table 2). However, in this type of study, the exponential decay rate possibly overestimates the decay time of the seed as the seed/soil mix was enclosed in a nylon mesh bag and this would exclude some important predators such as earthworms.

TABLE 2: Predicted time (years) for the seed to reach 1% viability in the four soil types at three depths.

Soil depth (cm)	Soil type							
	Horotiu Years	R ²	Dunmore Years	R ²	Rukuhia Years	R ²	Hamilton Years	R ²
0 - 2	6	0.55	7	0.83	5	0.75	3	0.77
5	79	0.57	35	0.82	22	0.89	14	0.86
20	67	0.91	32	0.79	33	0.95	16	0.88

Of the four soils used in our study, nodding thistle seed retained the greatest viability in the Horotiu sandy loam soil and least viability in the Hamilton clay loam soil (Figure 2). The Hamilton clay loam soil has a heavier texture, lower water holding capacity and is more prone to drying and these characteristics are probably associated with the more rapid depletion of the weed seed. Closely located sites with virtually identical climates and similar management histories, but with different soil types, may yield quite different weed floras and weed densities (Rahman and James 1993).

The weed seed bank normally declines exponentially and this is readily explained in terms of biological processes (Thompson and Makepeace 1983; Rahman *et al.* 1998). Therefore this model was used to examine these results and regression lines were fitted to logarithmic transformed data (Figure 2). The decline in the viability of the nodding thistle seed differed appreciably between soils. The times for the amount of viable seed to be reduced to 1% of the original number at various depths were calculated and are presented in Table 2 along with the R² of the fit. These data confirm that in the absence of fresh seed input in the top layer of the soil, it only takes a few years for the seed bank to decline to 1%. However, if the seed is quickly buried, (by worms, pugging, falling down cracks or by cultivation), then it could take up to 80 years for seed viability to decline to this level.

FIGURE 2: Percentage of viable nodding thistle seed germinated at a) 5 cm and b) 20 cm depths in four different soils (average of three replicates).

The extended persistence of nodding thistle seed in the soil suggests that a long period of time is required for natural depletion of the seed bank despite the favourable climate for germination through much of the year in Waikato. This may prove advantageous in situations where resistance to phenoxy-herbicides has occurred by ensuring the presence of a large reservoir of non-phenoxy herbicide resistant seed (Harrington and Popay 1987; Bonner *et al.* 1998). In general however, this long-term viability of buried seed and the often frequent addition of new seed to the soil surface, will mean that a continuous effort is essential for satisfactory management of this problem weed. This should involve approaches that either leave the seed buried in the soil (e.g. conservation tillage) or involve the use of herbicides or other control measures (e.g. biological control) that destroy weed seedlings in early stages of growth.

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