SEED BANK ACCUMULATION OF BROOM (*CYTISUS SCOPARIUS*) IN SOUTH ISLAND

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ABSTRACT

The rate and pattern of seed accumulation in soil (<5 cm) beneath pioneer broom plants invading grassland was studied in Nelson/Marlborough and Otago. In both regions plants accumulated a mean of <200 seeds/m² by 4 years of age. By 6 years this rose to 1200 seeds/m² in Nelson/Marlborough and 400 seeds/m² in Otago. Seed spread relative to canopy diameter was greatest in plants up to 4 years old. Thereafter, an increasing proportion of seeds fell within the canopy. In Nelson/Marlborough, mean seedling establishment around pioneer plants increased from 0.05 seedlings/m² in the 3-4 year age class to a maximum of 0.6 seedlings/m² in the 7-8 year class. Some plants in all age classes had no effective regeneration. Control efforts will be most effective in limiting the spread and persistence of broom if directed towards young (<4 years) outlying plants.

Keywords: *Cytisus scoparius*, broom, seed banks, seed dispersal, weeds

INTRODUCTION

Broom (*Cytisus scoparius* (L.) Link) is a globally invasive European shrub, eg. Australia (Waterhouse 1988), North America (Bossard 1991), India (Agrawal *et al.* 1961), and Japan (Nemoto *et al.* 1993). It is widely distributed in New Zealand (Webb *et al.* 1988), especially in montane North Island and eastern South Island where it is still spreading onto pastoral country and conservation land (Williams 1981; Bascand and Jowett 1982).

Weed spread occurs both at the invasion front resulting from deterministic short-distance dispersal and in the broad establishment zone ahead of the front resulting from stochastic long-distance dispersal (Auld *et al.* 1979; Wilson and Lee 1989). The elimination of isolated plants in the latter zone offers the greatest potential savings of future control costs and hence the greatest return on expenditure (Mack 1985). This is especially so for plants such as broom with large and persistent soil seed banks (Bossard 1991; Partridge 1989; Smith and Harlen 1991; Williams 1981).

We investigated the spatial and temporal patterns of soil seed bank accumulation around pioneer broom bushes of different ages in two regions of the South Island.

METHODS

Study sites were located in grassland in Nelson/Marlborough (northern area) and Otago (southern area) with no known history of disturbance since broom first established, to maximise the probability of sampling first-generation broom bushes. In the north, 45 plants were sampled at six sites located near Hanmer and Kawatiri Junction (altitude 380-880 m; annual rainfall 640-1400 mm). In the south, 42 plants were sampled at 11 sites (altitude 40-580 m), most within 50 km of Dunedin (annual rainfall 785 mm), and the remainder near Roxburgh and Alexandra (annual rainfall 400 mm).

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Maximum canopy diameter of each bush was measured, the stem was cut at ground level, and age was determined from the number of growth rings. The seed bank associated with each plant was sampled from circular plots by taking soil cores, 5 cm deep and 7 cm (northern area) or 10 cm (southern area) in diameter, at 0.5 m intervals along 7 m transects perpendicular to and parallel with the contour, with their midpoints intersecting at the sampled stem. In the northern area the number of broom seedlings (<20 cm tall) in each circular plot was recorded. The 28 samples from each plant were wet-sieved, and all broom seeds were counted. Seeds from several southern sites were weighed and their viability tested with tetrazolium (0.5% w/v in water).

RESULTS

Seed weight was 4.6-15.3 mg with a mean of $9.38 \text{ mg} \pm 1.97$ (s.d.), and seed viability was 90-100%. Seed densities in all four directions away from the stem were similar, so data from all radii were bulked for other analyses.

TABLE 1: Mean seed densities and range (seeds/m²) over 3.5 m radius sample plots in each age class, northern and southern sample areas, first generation plants only. n = number of plants in sample.

Age class	Density	Northern Range	n	Density	Southern Range	n
2	-	-	-	141	-	-
3	101	0-276	4	117	0-514	7
4	101	0-358	4	140	0-623	5
5	550	37-1528	8	66	0-227	11
6	1213	0-2730	6	421	0-842	2
7	763	130-1551	5	214	27-418	4
8	865	104-1421	6	9	-	1
9	2649	-	1	-	-	-
10	833	149-2031	3	-	-	-
11	402	84-845	6	0	-	1
12	-	-	-	883	-	1
13	-	-	-	0	-	1
14	1226	139-2312	2	-	-	-

In the *northern area* most plants were 3-11 years old, with two at 14 years (Table 1). All 3- and 4-year-old plants had seed banks of <500 seeds/m², with a mean density of about 100 seeds/m². Linear regression showed no significant relationship ($P > 0.05$) between plant age and mean seed density over all sites, for although mean seed density increased steeply up to 6 years, it was very variable thereafter, partly because of the relatively small sample sizes of 9, 10 and 14 year age classes (Table 1).

The linear regression of canopy diameter on age was significant ($y = 0.11x + 0.98$; $P < 0.01$; $R^2 = 0.20$). The proportion of seeds deposited outside the mean canopy radius varied: approximately 55% in plants 3-4 years old, 46% at age 5-6, 30% at age 7-8, and 64% at age 9-14. Seed density at the 3.5 m limit of sampling remained similar and low (<300/m²) with increasing age.

Seedlings first appeared within the 3.5 m radius of individual bushes at 3-4 years and reached a peak of 22 seedlings per plot (2.3/m²) around plants 7-8 years old (Fig. 1).

In the *southern area* most plants sampled were 3-7 years old (Table 1). Mean seed density was very variable (Table 1) and the linear regression of mean seed density on age was not significant ($P > 0.05$). Several plants of a range of ages had no seeds. Relatively high seed densities (>500/m²) occurred with individual plants 3, 4, 6, and 12 years old but, apart from the 12 year class, mean densities in each age class were <500/m² (Table 1).

FIGURE 1: Mean number of broom seedlings (stems <30 cm tall) in plots of 3.5 m radius surrounding first-generation broom plants of four age classes, Nelson/ Marlborough area.

Canopy diameter increased significantly with age (linear regression $y = 0.17x + 0.85$; $P < 0.001$; $R^2 = 0.25$). A variable proportion of seeds fell outside the canopy edge with increasing age class: about 55% at 2-4 years, 25% at age 5-6, 54% at age 7-8 years, and 40% at age 11-13. In all age classes seeds were distributed to at least 3.5 m from the stem. Mean seed density at the 3.5 m limit of sampling remained at $<100/\text{m}^2$ for plants up to 6 years old, but increased to nearly $200/\text{m}^2$ at age 7-8 and to $>200/\text{m}^2$ in the 9-13 year age group.

DISCUSSION

Isolated individuals of invading populations have the greatest capacity to contribute to population expansion (Mack 1985; Hengeveld 1989). In the case of broom, the reproductive capacity of individuals varies widely depending on environmental conditions, eg. second year plants grown over a range of sites produced between 680 ± 490 (s.d.) seeds/ m^2 and 40 ± 28 (s.d.) seeds/ m^2 (Williams 1981; data reworked for 3.5 m radius). Such variability helps to explain some of the outcomes of the present study.

In grassland, isolated bushes become conspicuous in their second or third year of growth. In the northern area there is a clear relationship between plant age and seed bank size for the first years; there are c. 1000 seeds/ m^2 after 6 years, and numbers increase to c. 3000/ m^2 in older bushes. In the southern area the relationship was partly obscured by the wide environmental range of the sites. Even so, seed numbers reach $>400/\text{m}^2$ after 5-6 years and a maximum of nearly 900/ m^2 thereafter. Overall, seed banks of pioneer bushes accumulate only slowly after 6-7 years as seed production levels off (Smith and Harlen 1991), and presumably inputs are matched by losses.

Several factors contribute to the low seed and seedling densities around many older isolated bushes, including an intrinsically low reproductive success, degeneration of old plants (Williams 1983; Smith 1994), germination of a proportion of seeds after burial (Smith and Harlen 1991) which removes them from the seedbank, and animal browsing constraining seed production and removing seedlings, resulting in bushes remaining isolated.

Most broom seeds are deposited within the parent canopy, where they contribute little to stand expansion. Even so, the area of seed accumulation (out to 3.5 m radius from the stem) is 16 times that of the average plant canopy (0.85 m radius) in the 3-4 year age group. Thereafter mean canopy diameter increased only to 1.5 m, and the area of seed distribution increases little unless the seeds are dispersed by means other than explosive dehiscence. This dispersal pattern, coupled with the rapid height growth of young bushes (Williams 1981), explains the sharp boundaries between isolated stands and surrounding grasslands that characterise broom invasions.

Plants that establish from seed produced by their parent in its third year, and at 3.5 m from the parent stem, correspond to an invasion front moving at 1.16 m per annum. This is close to the 1.3-1.5 m per annum recorded in California (C. Bossard pers. comm.). Invasion rates greater than 1.5 m per annum are dependant on factors other than explosive dehiscence.

The practical implications of these observations are as follows.

- (1) Plants which are dispersed other than by explosive dehiscence are the primary influence on the rate of spread, and thus should be priority targets for weed control.
- (2) Where broom plants younger than 3-4 years have established from isolated seeds, it can be assumed there are few seeds in the soil.
- (3) Failure to detect and eradicate bushes in their second or third year will result by the third or fourth year in a 16-fold increase in the area infected by broom seeds, and establishment of a substantial soil seedbank.
- (4) Because bushes older than 4-5 years have a seed bank, their destruction will not prevent establishment of seedlings at the invasion front represented by deterministic short-distance dispersal. In contrast, eradication of younger isolated bushes before they seed will prevent the seed bank from developing, and hence represents a more efficient form of control.
- (5) As seed production and seedling survival from outlying individuals is highly variable and unpredictable owing to genetic and environmental factors, control measures should target all outliers. Delaying control for even 1 year is highly undesirable.

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