Variation in gorse (*Ulex europaeus* L.) seed production and viability in the South Island of New Zealand

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Abstract

To investigate whether gorse (*Ulex europaeus* L.) seed viability was influenced by altitude or climatic conditions, six sites were chosen in South Island, New Zealand. These sites had different soil types, altitudes, annual rainfall and mean monthly temperatures. Monthly inspections took place and when blackened pods were present, samples of 25 pods were collected. Mature seeds were also collected by placing trays under bushes to catch seeds as they fell. Gorse seed collected in the trays had a viability of 60%, whereas seed from pods sampled from the plant had a viability of 80%. There were significant differences in monthly seed fall germination ($P < 0.01$) but there were no significant differences among sites in seed fall germination. Spring – summer produced seed showed significant differences among sites ($P < 0.05$), with seed produced in Golden Bay showing more viability.

Additional key words: Altitude, climate, germination, gorse, seed viability.

Introduction

Gorse (*Ulex europaeus* L.) was introduced into New Zealand as an inexpensive, quick-growing hedge for stock containment and shelter (Moss, 1960). However, it soon became a weed and was declared a noxious weed in 1900 (Cowley, 1983). Due to the favourable climate for its growth in much of New Zealand, gorse has two reproductive periods a year, one in spring and the other in autumn. Gorse is a prolific seeder and the seed is viable for at least 40 years (Zabkiewicz, 1976; Zabkiewicz and Gaskin, 1978). The ability of gorse seed to remain viable for many years, requiring only to be brought nearer to the soil surface for germination to occur, means that the weed can rapidly re-establish gorse infestations (Ivens, 1982).

The aim of this study was to compare the viability of both gorse seed fall and gorse seed from sample pods taken from gorse bushes at different sites in the South Island of New Zealand to see if gorse in the colder regions had a different level of seed viability than gorse seed produced in warmer areas. In a year gorse produces many seeds but it is not known what proportion of that seed production is hard or dead. The purpose of this study was to investigate the viability of gorse seed.

Materials and Methods

Sample sites

Three sites were at Golden Bay; Bainham, Onekaka and East Takaka. The other three sites were south of Christchurch; Hinewai, McLeans Island, Trotters Gorge and Lake Ohau (Figure 1). At each site fifteen bushes were selected using a random number chart, (1-20) which was used as the distance between bushes (metres). Sites were inspected monthly and samples of 25 mature pods were collected when they were available. McLeans Island did not produce any black pods or seed fall, due to attack by several biological control agents, especially the gorse stem miner (*Anisoplaca ptyoptera* Meyrick).

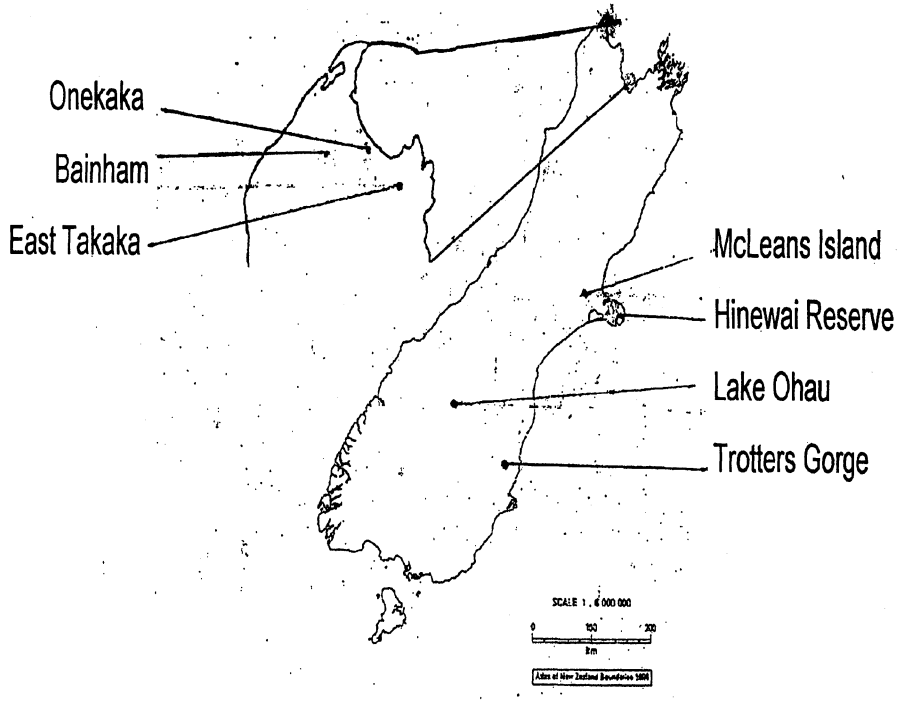


Figure 1. Map of South Island, New Zealand showing locations of study sites.

Table 1: Average gorse bush height (cm).

Site	Bush height	SD
Bainham	267	56
Onekaka	259	93
East Takaka	205	59
Hinewai	129	55
Trotters Gorge	189	67
Lake Ohau	92	58

The size of gorse bushes varied (Table 1) and this could be due to climatic conditions, age of bushes or the level of soil nutrients. No core sampling was done to determine the age of the bushes, nor were any soil samples taken to measure soil fertility.

Seed sampling

One seed tray was placed under each selected gorse bush. Seed fall from the sampled bushes was collected in circular 24.5 cm diameter seed trays (1,481 cm^2 area). This was converted to the number of seeds/m^2 by multiplying by 6.75. Fallen seed was collected continuously from March 2002 – March 2003. Seed from the trays was removed at monthly intervals for analysis. At the same time the plants were inspected for their stage in their reproductive cycle.

When the gorse pods on the bushes were black, a sample of 25 pods was taken from each sample bush. Seed was stored in paper bags at 4°C until required for germination testing. Both fallen seed from the trays and seed from the pod samples were tested for their viability.

Seed surface sterilisation

For germination tests, all equipment used was sterilised in an autoclave and only sterilised water was used. To minimise the risk of fungal and bacterial infection, seed samples were washed in 2.5% sodium hypochlorite (NaOCl) for 5 min. Seed was then rinsed and air-dried overnight at room temperature.

Scarification

Sixtus *et al.*, (2003a) showed that scarification of gorse seed with concentrated sulphuric acid (H_2SO_4) (36N) for 180 min gave the highest seed germination. The same experiment also showed that the optimum temperature for gorse seed germination was 15°C.

Fallen seed was inspected prior to acid scarification to ensure that no damaged seed was being scarified. Two volumes of acid to one volume of seed were used (Hartmann *et al.*, 2002). Seed samples were placed in the acid for 180 min. Following acid treatment, seed was washed in running water until the pH was neutral and the seeds were then rinsed in sterile water. After rinsing, the seed was placed in Petri dishes for germination testing. All seed collected from under each bush was placed in a dish regardless of the number of seeds. For pod samples, there were 25 seeds/dish.

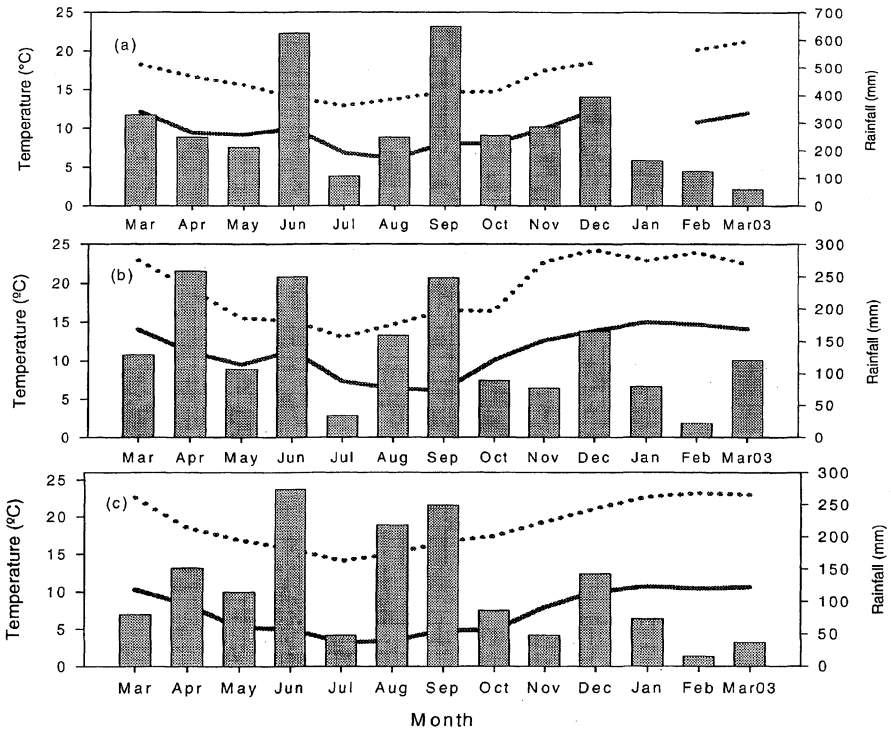
Germination temperature

The germination cabinets were set at a constant 15°C with a 16 h light and 8 h dark cycle. Seeds were placed on moist germination paper in a Petri dish and germinated for 10 days. Dishes were inspected daily and extra sterilised water was added as required.

Data collection and statistical analysis

The total number of germinated seeds was counted 10 d after scarification. A seed was counted as germinated when it showed a radicle that was at least the length of the seed. Seedlings were not classified as normal and abnormal.

Data were analysed by analysis of variance using the SYSTAT 9 package.



NB: the scale of the rainfall axis of Golden Bay differs from the southern sites
Note: Temperature not measured at Bainham in January
Onekaka rainfall data obtained from Kotinga
East Takaka temperature data obtained from Kotinga
Lake Ohau temperature data obtained from Tara Hills
Lake Ohau rainfall data obtained from Chain Hills
Trotters Gorge rainfall and temperature data obtained from Oamaru and Palmerston

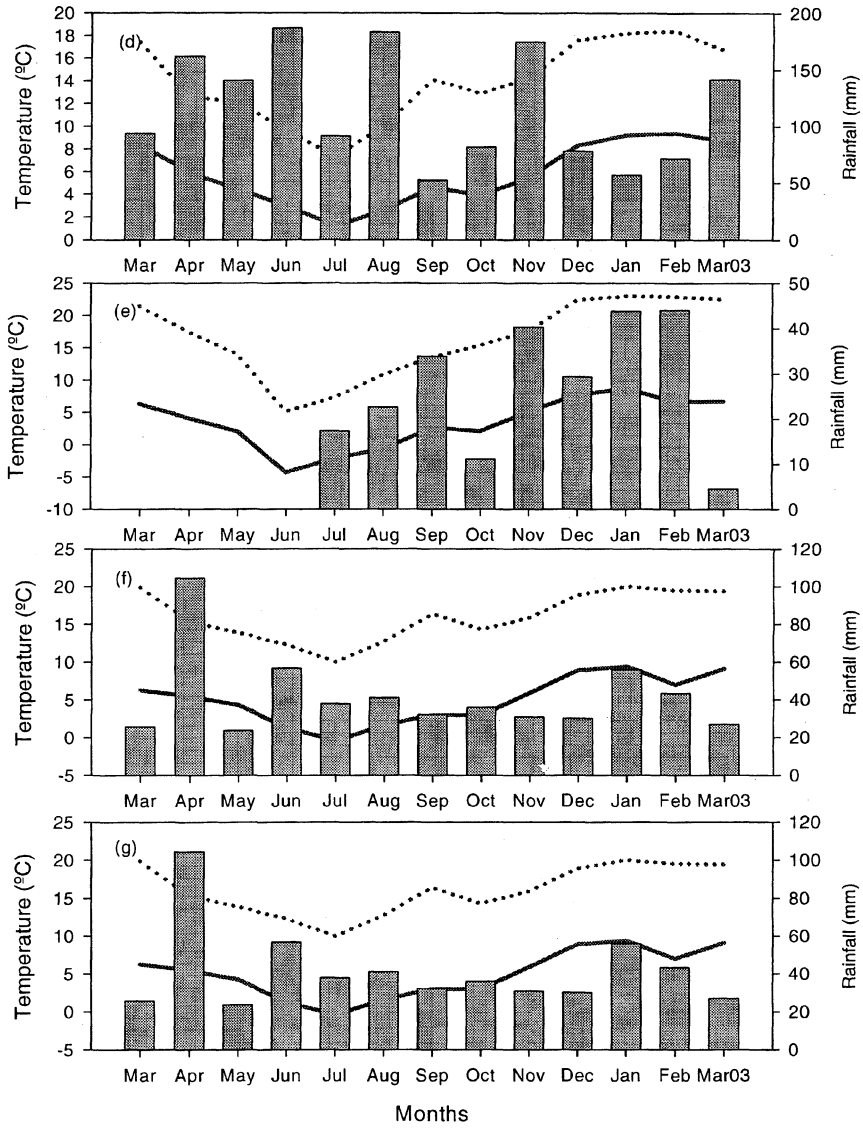


Figure 2. Average maximum and minimum temperatures and monthly total rainfall for each of the experimental sites. (a) Bainham, (b) Onekaka, (c) East Takaka, (d) Hinewai, (e) Lake Ohau, (f) Oamaru, (g) Palmerston (f and g Trotters Gorge).

Table 2: Average monthly number of gorse seeds per 25-pod sample from six collection sites (± SD) during months when ripe pods were present

	Bainham	Onekaka	East Takaka	Hinewai	Trotters Gorge	Lake Ohau
May	45.2 ± 21.1	33.8 ± 20.9	63.7 ± 30.6	nrp	nrp	nrp
June	80.2 ± 65.1	79.1 ± 31.1	69.9 ± 16.7	nrp	nrp	nrp
July	57.8 ± 22.5	78.8 ± 20.4	67.1 ± 16.9	nrp	nrp	nrp
August	58.6 ± 21.4	69.9 ± 29.7	62.7 ± 25.8	nrp	nrp	nrp
September	85.3 ± 16.1	75.8 ± 25.7	70.7 ± 18.9	nrp	nrp	nrp
October	70.4 ± 26.3	82.7 ± 22.8	83.6 ± 19.7	nrp	nrp	nrp
November	94.4 ± 22.5	86.9 ± 18.4	69.4 ± 16.0	nrp	nrp	nrp
December	74.6 ± 20.8	45.2 ± 23.0	48.6 ± 21.6	nrp	nrp	17.3 ±10.6
January	30.7 ± 25.4	32.8 ± 31.9	53.5 ± 3.1	21.0*	51.5 ± 18.7	16.4 ± 14.6
February	91.0*	nrp	nrp	58.7 ± 23.6	55.5 ± 15.4	nrp
March	nrp	nrp	nrp	46.0 ± 25.4	59.3 ± 1.2	nrp

nrp = no ripe pods present. *Only one sample collected.

Results

Climate

Daily minimum and maximum temperatures were recorded using thermo-hygrographs and monthly total rainfall was recorded from March 2002 to March 2003 (Figure 2).

Seed counts

The field results showed that gorse produced mature seed pods almost continuously in the Golden Bay region. However, in the southern regions it produced seed only in the spring. The seed fall for each month varied from 0 – 256 seed/m^2 (Figure 3). Table 2 shows the mean number of undamaged seeds from pods picked per site per month, varied from 16.4 to 94.9 seeds/25 pods.

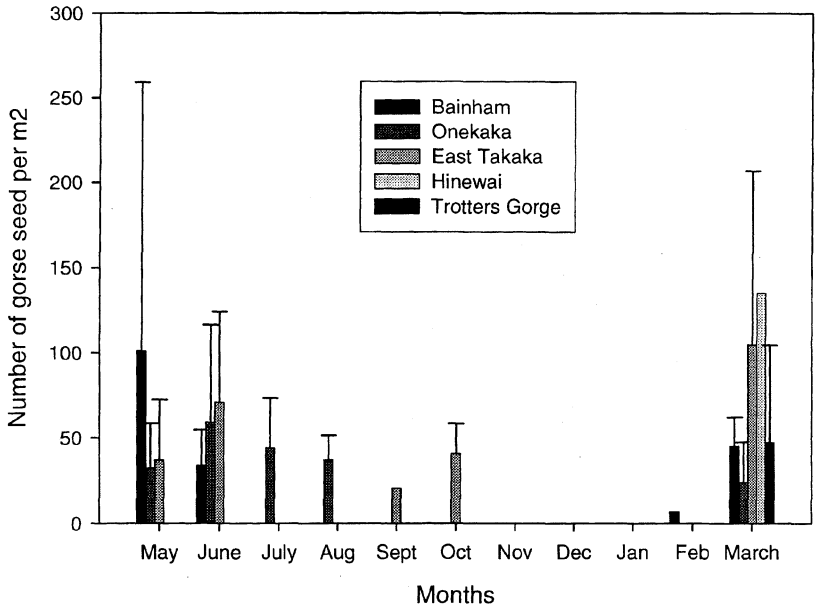


Figure 3. Monthly gorse seed fall during the study at the six study sites (seed/m^2) (I = SD).

Comparison of results between collection sites

To compare results between sites, three studies were completed on the sampled gorse seed. The first was among seed fall samples collected in the trays. This study was completed whenever there were seeds present in the seed trays over the 12-month period (Figure 4a). No seeds fell into seed trays at Lake Ohau.

The second study compared the viability of seed in the sampled pods at all six sites (November 2002 – March 2003) (Figure 4b). The third study investigated the sampled pods taken over the whole study period from the Golden Bay sites (Figure 4c).

The results for the seed fall tests showed there were significant differences in the monthly seed fall germinations ($P < 0.01$). However, there was no significant difference between sites (Figure 4a), but the month × site interaction was($P < 0.07$.

A comparison of all six sites over the summer showed that the southern sites had

significantly lower seed germination levels than the Golden Bay sites. The Golden Bay pod samples were significantly different among sites ($P < 0.05$). However, month-to-month there was no significant difference in germination.

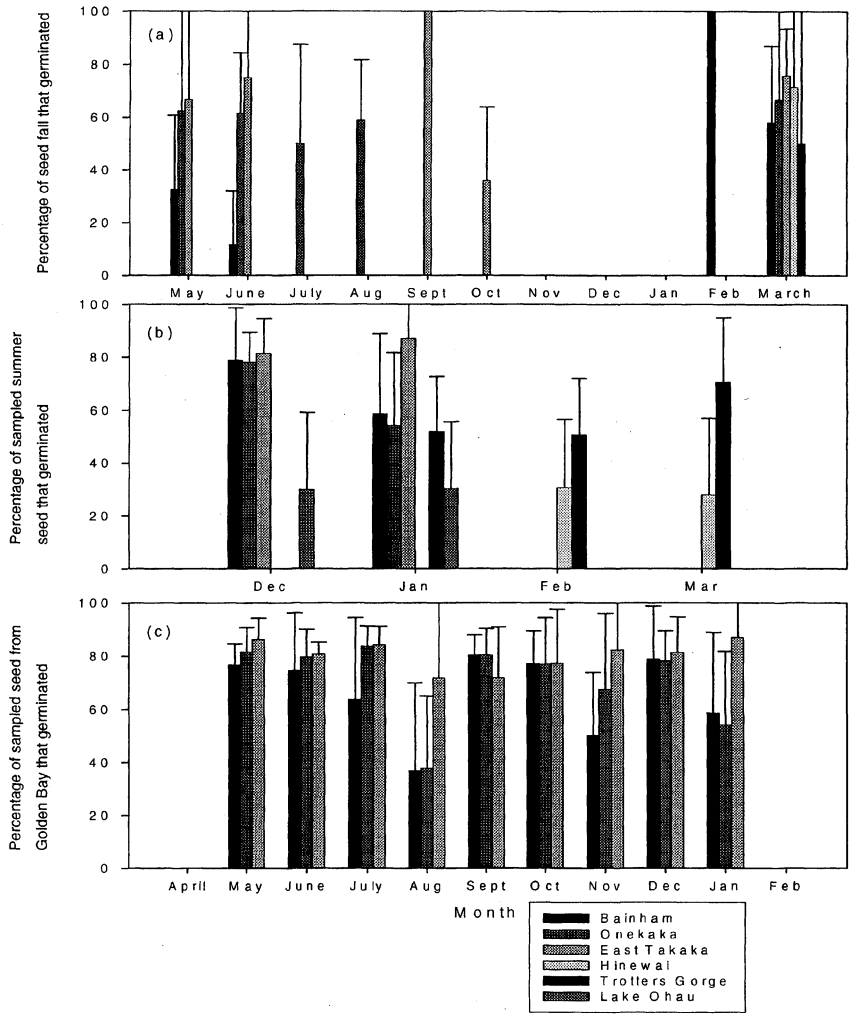


Figure 4. Monthly gorse seed germination (%), a) seeds that had fallen into seed trays; b) seed sampled from the six sites during spring-summer; c) seed sampled from Golden Bay sites over the total experiment. (There were no seed fall in trays at Lake Ohau) (I = SD).

Discussion

The aim of this work was to ascertain the effect of climate on annual gorse seed fall in two parts of the South Island of New Zealand. The viability of fallen gorse seed was tested and, as a comparison, the viability of seed taken from gorse pods still on the bushes was tested over the same period. Comparisons among sites were used to ascertain whether or not seed viability differed at the different sites.

The total number of seeds caught in the seed trays for each sample site varied from 0 - 256 seed/m^2 (Figure 3). Previous studies of annual gorse fall at Palmerston North by Ivens (1978) found the seed fall was 500 – 600 seed/ m^2. In Ivens's (1978) study there were four seed trays placed under each bush, whereas in the current study, there was only one bush. Although there were 15 bushes/site, the majority of sites were in areas that were grazed by livestock. This meant that the seed trays had to be placed as close to the trunk as possible, to avoid stock damage to the trays, and the loss of any seed that had been collected.

There was a marked difference between sites in annual gorse seed production, as well as in the length of the reproductive phase of the plants. The Golden Bay sites produced seed almost continuously, with production peaks in June 2002 and in December – January 2002-03. At the southern sites, there was only one reproductive period, during the spring-summer (Figure 4). This is possibly because of the harsher winter conditions at the southern sites. Figure 2 shows the average monthly minimum temperatures during the winter in the southern regions were below 0 °C or close to 0 °C. In Golden Bay, the average monthly minimum winters temperatures were considerably higher at approximately 5 °C and this could have giving the longer reproductive period per season.

The germination of all fallen seed was similar, regardless of soil type, climatic conditions or site altitude. However, there were month-to-month differences. This indicates that there are periods of the year when gorse seed is less viable. This was particularly so with the fallen seed from the Bainham site, where the autumn/winter fallen seed had a germination of 10 – 30 % (Fig. 4a).

Seed from pods sampled during summer showed that, in Golden Bay, gorse seed viability (60 %) was higher than seed produced further south (30 % at Lake Ohau). This higher germination combined with the prolonged seed production season makes Golden Bay an ideal area for gorse seed production. The Golden Bay seed from the pod samples also had high seed viability throughout the year (approximately 80 %) over the whole experimental period (Fig. 4c).

Lake Ohau seed was less viable (30 %). Sampling of immature pods may have caused this although care was taken when sampling to ensure that only black pods were picked. There was no seed fall at this site, due, in part, to the presence of *Exapion ulicis*. A high percentage of sample pods contained *E. ulicis* larvae.

At all sites, seed caught in the seed trays had a lower germination than picked seed, apart from those at Hinewai. This is contrary to the results of Ivens (1983), who found gorse seed from the soil germinated at 95 %; collected in trays under gorse bushes germinated at 66 % and seed from ripe pods germinated at only 37%. Thus there was a higher proportion of hard seed in seed from pods than in seed collected from seed trays and very little of the seed from the soil was hard. However, it is not clear if Ivens (1983) attempted to break down the hard seed, or if he did, how it was done.

In this work, seed from the trays and from the pods all had the same scarification treatment. Seed from Golden Bay, especially East Takaka, had a consistent germination of 80 % from sampled pods. However, the percentage of germinated seeds from the seed fall trays was considerably lower at 60 %. This reduction in seed germination may have possibly been caused by the use of concentrated sulphuric acid, where the seed fall did not have a hard coating. However

(Hill, pers. comm.) has found no reduction in soft white clover seed germination after immersion in concentrated sulphuric acid for 90 min. At Hinewai and Trotters Gorge the highest level of viable seed was from the seed trays at approximately 50 %.

Pods shattering, when the seeds were ripe, may have resulted in seeds being thrown further than the seed tray. Most seed falls directly below the gorse plant, although seeds can be thrown up to 5 m from the parent plant at pod dehiscence (Moss, 1960). Also worth considering was bush size. Many of the sample bushes at Golden Bay, Hinewai Reserve and Trotters Gorge were over 2.5 m high and covered a considerable area. Gorse seed production takes place in the leaf axils of the previous year's growth (Clements *et al.*, 2001) and parts of the bushes producing seed may have been outside the direct fall to the seed trays. Further research is needed to determine the effect of placing seed collection trays at various distances from the trunk.

Another factor in the reduction of seed fall into the seed trays may have been due to gorse seed biological control agents having an effect and reducing production of viable seed. The initial release of the gorse pod moth (*Cydia succedana* (Denis & Schiffermüller)) was in 1992 and it has now established throughout New Zealand. Pods damaged by *C. succedana* larvae were found throughout the study at the Golden Bay sites. Pods damaged by *C. succedana* often contained no seed as it had all been destroyed. *Exapion ulicis* had a marked effect on the amount of undamaged seed produced, with more effect further South.

There was no damaged seed scarified although Sixtus *et al.*, (2003b) found that seed lightly damaged by *E. ulicis* was still viable. Only seed from picked pods that were not damaged by *Cydia succedana* or *Exapion ulicis* was scarified.

Conclusion

Seed collected in trays was less viable (60 %) than seed from pods sampled from gorse bushes (80 %). Golden Bay pod sampled seed and seed fall seed had a higher viability than seed from Canterbury and North Otago (80 % v 50 %). Lake Ohau seed was even less viable seed (30%) and seed was produced for a shorter period, which may have been due to the colder climate at this site. Less viable seed was produced than previous studies, which may have been caused by the biological agents *Cydia succedana* and *Exapion ulicis.*

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