Controlling Gorse Seed Banks

John Moore, Libby Sandiford, Liz Austen and Grey Poulish.
Department of Agriculture and Food Western Australia, 444 Albany Highway, Albany, WA, 6330, Australia

.

Summary Gorse (*Ulex europaeus* L.) is a major agricultural and environmental weed in many parts of the world and has a persistent seed bank. Several techniques were investigated to either kill the seed or encourage it to germinate. Scarification of the seed coat resulted in almost complete germination of seeds. Smoked water had little effect on intact seed and high concentrations killed scarified seed. Gorse seed tolerated soaking in many organic compounds, however two bipyridyl herbicides at approximately 100-125 kg a.i ha^{-1} killed seed. Low levels of microwave radiation tended to increase germination and at high levels killed seed. Solarization did not give adequate control of seed banks. Gorse seed germinated over a range of temperatures from 14-24°C and appeared to have a bimodal optimum. Nearly all the seed is in the top 20 cm of soil and occurs within a few metres of the parent plant and seed will not establish from depths of more than 10 cm, so burial of isolated patches is a possible control technique. Potential seed bank control techniques and further research are discussed.

Keywords Gorse, furze, *Ulex europaeus*, seed, seed banks, control, herbicides, paraquat, diquat, solarization, smoked water, hydrocarbons, temperature.

INTRODUCTION

Gorse (*Ulex europaeus* L.) has a large and persistent seed bank that thwarts most eradication efforts. To break this seed bank, the seed must be killed, transferred to a situation where it can't establish or encouraged to germinate so it may be controlled by other methods. The effects of smoked water and other hydrocarbons, microwave radiation, solarization, scarification, temperature and burial on seed germination and viability were investigated to find potential techniques for eliminating seed banks. The distribution and size of seed banks in typical infestations was determined to help formulate strategies for control.

MATERIALS AND METHODS

Unless otherwise stated the methods below apply to all experiments. Gorse seeds used in all experiments were collected from sites around Albany, Western Australia. Seed was collected from mature pods, placed in brown paper bags and placed in an oven at 40°C for 24 hours. Bags were shaken to release seed, and the remaining seed extracted by a rubber belt thresher. Seed was hand sorted to exclude damaged or immature seed. After the treatments, seed was placed in glass petri dishes on Whatman No. 3 filter paper and placed in the dark in a germination cabinet at 15-19°C. Seeds were kept moist by watering with de-ionized water as required. Seeds were scored as germinated when at least 2 mm of radicle had emerged from the seed coat. Genstat 7 was used for statistical analysis.

1) Smoked water Hand scarified and intact seed were soaked in six different concentrations (0%, 1%, 5%, 10%, 25% and 100%) of two different smoked water solutions for 24 hours. Six replicates of 25 seed were randomly allocated to each treatment. Smoked water solutions were Regen 2000® and gorse smoke obtained by smoldering dry gorse remaining from the seed threshing in a sealed kettle and bubbling the smoke through 250 ml of de-ionized water for 6 hours using compressed air. Each treatment was sprayed with a 1 % P-Pickel T® (480 g/kg thiram + 266 g/kg thiabendazole) solution to reduce fungal infection. To reduce movement of any volatile compounds the six replicates in each treatment were sealed in separate zip lock plastic bags and randomly placed in the growth cabinet. Seed germination was recorded every 2-3 days for 62 days.

2) Hydrocarbons Fifty intact seeds were placed on filter paper in glass petri dishes and wet with a 5% solution of the 53 different products (herbicides, fungicides and other hydrocarbons). Seed germination was recorded weekly for 40 days after which obviously dead seed were counted and removed. Intact seed was hand scarified and replated with subsequent seed germination recorded twice weekly for 42 days to determine viability. Abnormal seedlings were noted.

3) Temperature Seeds collected from pods and soil were placed on a moist temperature plate with a gradient from 13-26°C. Germination was recorded at weekly intervals for 10 weeks.

4) Microwave radiation Scarified and intact seed were either soaked for 24 hours in de-ionized water or left dry then placed in Petri dishes and microwaved for 0, 10, 20, 40 and 160 seconds in a 800W microwave. Three replicates of 50 seeds were used per treatment. Germination was recorded 2-3 times per week for 67 days after which obviously dead seed was counted and removed. Sound seed was hand scarified and replated with subsequent seed germination recorded twice weekly for 28 days to determine viability.

5) Solarization 5000 scarified and 5000 intact seeds were each mixed with 7 L moist soil and spread to a depth of 7 cm in containers sunk into the soil. Approximately 14 litres of debris and soil from a gorse infested site were similarly treated. The area was covered with clear polythene sheeting on October 28, 2005. Temperatures were data logged at the soil surface, 2 cm deep and 6 cm deep under the sheet and at the soil surface outside the covered area. A quarter of each plot was excavated 4 months later and the seed tested for viability.

6) Scarification Scarification of the seed coat was achieved by individually removing part of the seed coat with a scalpel because rubbing between abrasives usually left some seed coats intact. Controls of all experiments were used to determine the effect of scarification. Additionally, seeds collected at six different times from three sites were subject to four treatments – scarified and intact seed that were sprayed with a 1% P-Pickel T® solution or water. Germination was recorded 2-3 times per week for 54 days.

7**) Seed bank and germination depth** The distribution of the seed in the soil profile was determined at four sites. Ten soil cores were taken from the canopy edge of gorse infestations and sections layered off at 1, 2 or 5 cm intervals. The ten samples for each layer were grouped and air dried in a glass house, sieved through 2 mm to 1.2 mm sieves and sample sorted by hand for seed. Maximum seed density estimates were calculated by grouping all 10 samples from the canopy edge. To determine if the soil seed was viable up to 25 seeds per layer were scarified and germinated in petri dishes as described above. Seed was sprayed with 1% P-Pickel T® solution.

The spread of seed was determined at two sites by taking ten samples at 0,1,2,3,4,5,6,7,8,9,10,15 and 20 m perpendicular to the canopy edge of two gorse infestations. Samples at each distance were grouped, dried and sieved as above. Sites chosen were flat and there were no overlapping gorse infestations.

To determine the maximum depth of germination, three replicates of 100 hand scarified seed were sown at 0, 1, 2, 5, 8 and 10 cm depths in 11.5 cm deep pots containing either paddock sand or a potting mix. Pots were randomly placed on racks in an unheated glass house and plants automatically watered twice a day. Pots were inspected weekly and plants counted as

recruitments and removed when cotyledons emerged for buried seed, or when the radicle had inserted into soil for surface planted seed. The position of pots was randomly rearranged each week. To determine the expected germination percentage six replicates of 50 scarified seed were germinated in a growth cabinet.

RESULTS AND DISCUSSION

1) Smoked water Smoked water had no effect on intact seed. On scarified seed there was similarly no stimulation of germination, but at high rates it was toxic to the seed (Figure 1). Regen® 2000 (R2000) solutions were more toxic than gorse smoke solution with 100% seed death occurring at concentrations of 25 % and above. For gorse smoked water, total seed death was only observed at the 100% concentration.

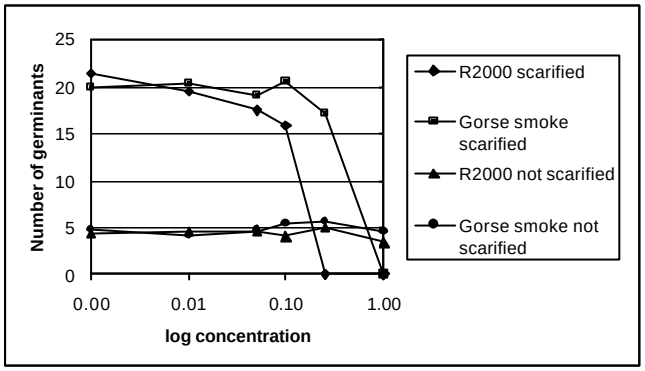

Figure 1. Effect of smoked water on gorse seed germination, l.s.d. $_{(p<0.05)}$ = 2.25

The lack of response by intact gorse seed to smoked water is probably due to the impermeable seed coat. Adkins and Peters (2001) and Read *et al.* (2000) have noted that smoke appears ineffective in promoting germination in seeds of other species with hard coats. Scarification of the seed leads to high levels of germination, but it is notable that germination in the remaining seeds is not promoted by smoked water. The inhibitory effects of concentrated smoked water (Regen® 2000) seed has also been found in other species (Adkins and Peters 2001). The difference between the commercial Regen® 2000 and the gorse smoked water is probably due to a difference in concentration of the active ingredient(s) because the dose response curve for each product is very similar and simply shifted along the axis (Kudsk *et al.* 1987).

2) Hydrocarbons Two herbicides, Reglone® (diquat 200 g L^{-1}) and Spray.Seed® (diquat 200 g L^{-1} plus paraquat 135 g L^{-1}), appear to kill all the seed treated with a 5% solution of the products. Five compounds reduced viability by more than 60% (Table 1). Forty six different compounds caused little or no useful reduction in seed viability. Initial germination in all compounds was lower than controls but this is probably just an osmotic effect. Abnormal seedling morphology including truncated, curled and discolored radicles or cotyledons were observed in many of these compounds. This is worthy of further investigation.

The paraquat and diquat rates tested are approximately equivalent to applying approximately 100-125 kg a.i. ha^{-1}. Lower concentrations are being tested. If these are effective, then further work needs to be done on delivering these doses to the gorse seed in the soil as the active ingredients are quickly inactivated by clays in the soil. Moore and Jettner (2002) have shown rates around 2 kg a.i. ha^{-1} of paraquat or diquat had little effect on germination but did reduce seedling vigor of barley seed.

Table 1. Summary of germination and viability % of seed treated with hydrocarbons.

Compound	Initial Germination %	Germination % Following scarification	% viability
Control non scarified	22	89	88
Control scarified	96	0	96
Reglone	0	0	0
Spray.Seed	0	0	0
Grazon (triclopyr + picloram)	0	40	32
Buctril (bromoxynil)	0	51	46
MCPA	0	69	55
Tordon (2,4-D + picloram)	0	53	46
Alto	0	58	53
46 other compounds	0-13.2	70-100	60-98

3) Temperature There appears to be a bi modal distribution of optimum germination temperatures peaking at 15.9 and 19.3°C (Figure 2). This may result in two flushes of germination e.g. winter and spring. Previous studies have found optimum germination temperatures for gorse of from 15-19°C (Zabkiewicz and Gaskin 1978, Ivens 1983, Sixtus *et al.* 2003). Some seed germinated over a wide range of temperatures and this has also been observed in overseas work (Ivens 1983).

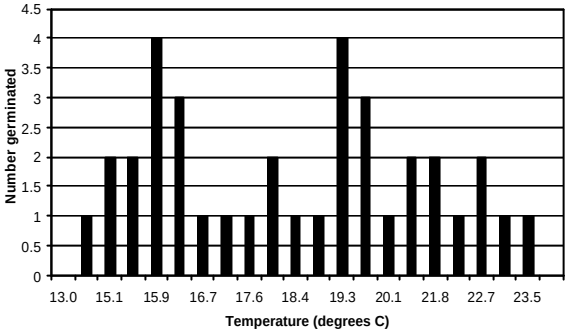

Figure 2 The effect of temperature on gorse germination.

(4) Microwave radiation High doses of microwave radiation killed gorse seed (Figure 3). Relatively low levels of microwave radiation killed gorse seed that had been scarified and soaked. A similar increase in toxicity and germination inhibition in water imbibed seeds of other species exposed to microwaves has also been found by Scarsbrook and Davis (1971) and Menges and Wayland (1974). Significant stimulation in seed germination was observed by microwaving intact soaked seed at 10, 20 and 40 seconds. The average germination peaked at 86 % at 20 seconds of microwaving compared with 18 % with no exposure to microwaves. The other two treatments had a similar trend. The effect of microwaves has not been tested in soil or at depth though

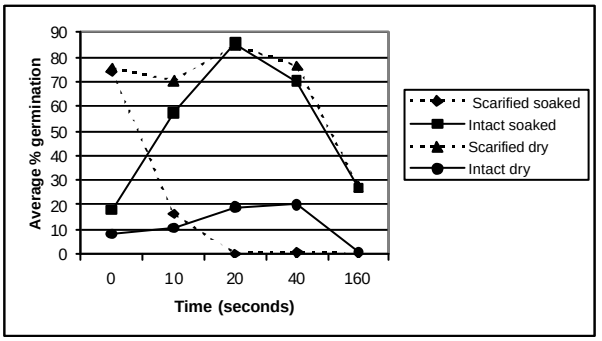

Figure 3. Effect of length of time of microwaving on gorse seed germination. s.e.d = 6.66.

Menges and Wayland (1974) demonstrated some weeds can be controlled in the soil using microwaves after seed had imbibed water from the soil.

As the objective of this work was to find treatments that would eliminate the gorse seed bank, Table 2 was prepared to show the

number of dormant and viable gorse seeds left after the various treatments. Scarifying reduced the potential numbers in the seed bank to very low levels because nearly all of the seeds germinated. Intact and soaked seed required 40 seconds of microwave exposure to either kill the seed or break its dormancy. Dry intact seed required 160 seconds of microwave exposure to achieve the same results. The difference is possibly due to the wet seed absorbing more radiation and consequently getting hotter quicker.

Table 2. The effect of various times of microwave radiation on pre-soaked or dry and scarified or intact gorse seed on the percentage of ungerminated seeds that were still viable 20 days after treatment.

Treatment		Microwave time (secs)				
Seed	State	0	10	20	40	160
Scarified	Soaked	0	0	0	0	0
Scarified	Dry	1	0	0	0	0
Intact	Soaked	79	37	9	0	0
Intact	Dry	88	84	72	76	0

5) Solarization Peak temperatures reached at the soil surface under clear plastic were occasionally up to 20°C higher than outside soil surface temperatures but usually < 10°C higher when measured at the hottest point of the day and rarely exceeded 60°C (Figure 4). At a depth of six cm, temperatures were usually less than 3°C higher than outside soil surface temperatures. Clear plastic had some insulating effects at night with temperatures at the soil surface under plastic being approximately 10°C higher than outside soil surface temperatures. Zabkiewicz and Gaskin (1978) found inhibition of gorse seed germination was not achieved in wet or dry seed until seed was exposed to temperatures above 100°C and that virtual sterilization occurred at 150°C. Under dry conditions, a complete loss of viability at 110°C and little loss of viability at 65°C for 48 hours is reported by Moore and Moore (2006). No gorse seedlings were observed under the plastic indicating solarization may affect recruitment. Temperatures at six cm deep were in the range of normal surface temperatures and therefore unlikely to have an effect on seed germination however Ivens (1983) has reported loss of viability of gorse seed at temperatures greater than 35 degrees C under wet conditions. Solarisation will need to be combined with other methods to provide effective control of the gorse seed bank.

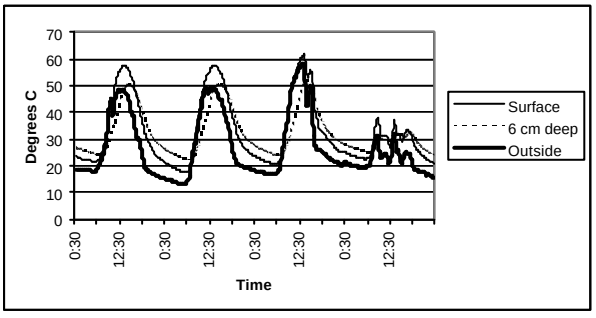

Figure 4. Typical temperature profiles at the surface and 6 cm below ground under clear plastic sheet and at the soil surface outside the sheeted area.

6) Scarification Scarified seed had much greater germination than intact seed (Figure 5). Scarified seed imbibed within 24 hours of wetting. In these experiments each seed was scarified by hand and the responses were similar to acid scarification but generally higher than those quoted in the literature where mechanical scarification is often used (Sixtus *et al.* 2003). Seed that had been mass scarified by rubbing between bricks or passing though rotating sandpaper disks still contained variable proportions of seed with intact seed coats. Better mechanical devices are required to achieve high levels of scarification. The results reported here are for seed that has been individually scarified by hand.

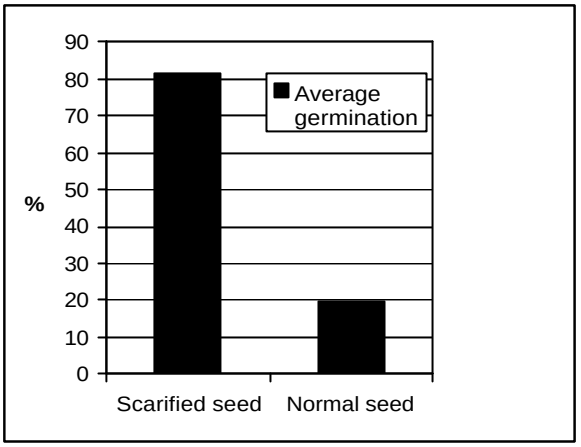

Figure 5 Effect of scarification on gorse seed germination**.** s.e.d.= 4.167

7) Seed bank distribution and depth of germination The densities of seed banks ranged from 2500 – 16000 seeds m^{-2} with the higher densities recorded after summer seed fall. The majority of gorse seed was found within the top 2 cm of the soil profile. In unburnt sites over 78 % seed was found within the top 2 cm (Figure 6). In a burnt site 46 % of seed was recorded in top 2 cm with the surface seed probably depleted compared to unburnt sites due to germination after fire. Where it was possible to sample the top 1 cm and 1-2 cm profiles separately the majority of seed were found within the top 1 cm of soil. Seed was recorded much deeper than expected at 15-20 cm deep. Worm castings were associated with this buried seed and earthworm activity may be responsible for seed burial though past cultivation cannot be ruled out as all sites were in cleared paddocks. The densities and distributions of seed through the profile in Western Australia was remarkably similar to that reported in Spain (Puentes *et al.* 1988) and New Zealand (Zabkiewicz and Gaskin 1978, Rolston and Talbot 1980).

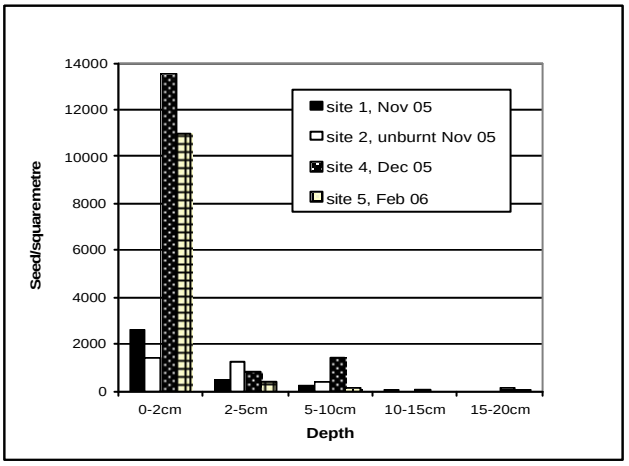

Figure 6. Distribution of gorse seed in the soil profile.

The majority of seeds were located at the canopy edge. At two sites 61 % and 63 % of seed was recorded at the canopy edge and 99 % of seed was recorded within 3 m of canopy edge (Figure 7). The maximum distance seeds were found from the canopy edge was 7 m. These results suggest a 5-10 m buffer for control measures would be sufficient. Similar distribution of gorse seed was recorded in New Zealand where the highest seed density occurred at the edge of the canopy with only 1.9% seed occurring at 2.4-2.5 m from edge of the canopy (Hill *et al.* 1996).

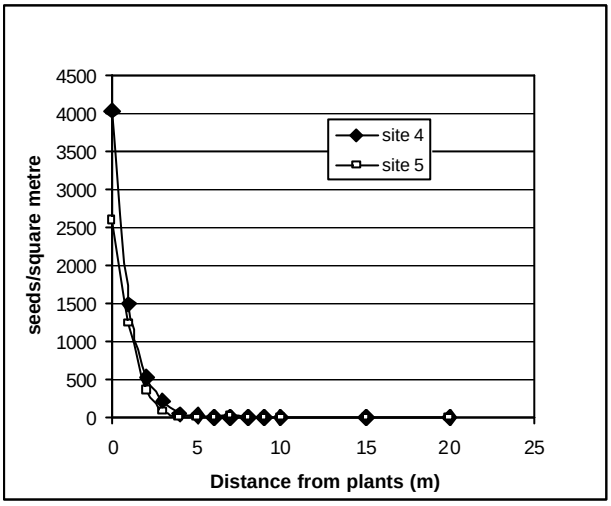

Figure7 Distribution of gorse seed from the canopy edge.

Maximum seed recruitment occurred with seed sown at a depth of 1 cm and no recruitment occurred below 5 cm (Figure 8). Very little recruitment occurred at surface level. Scarified seed germinated readily on the soil surface but most of it died from desiccation. Germination was higher at all depths in paddock soil compared to potting mix. Average germination for seed was 86.3%. These results confirm unpublished studies in New Zealand by R Hill (pers. comm.) who found no emergence of gorse seedlings below 5cm in pot trials.

Covering infested sites with 10 cm soil would effectively prevent recruitment providing it is not disturbed for many years.

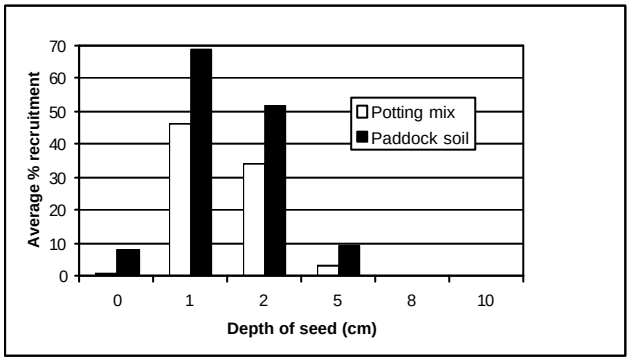

Figure 8 Average recruitment of gorse seed as different depth

CONCLUSIONS

Gorse seed is proving to be very resilient to a range of control techniques applied by us and others around the world. Scarification of the seed coat is effective for stimulating germination and further research into practical methods of achieving effective scarification by mechanical, chemical or biological methods is warranted. The occurrence of gorse in difficult geographic locations makes the biological and chemical methods particularly attractive. The effects of bipyridyl herbicides provide the most promise of a new solution. Further research is required to determine if effective seed control techniques can be developed because it will be difficult to deliver the herbicide to the site of the seed in the field. Investigation of biological agents including microorganisms that attack the seed coat especially in soil borne seed is warranted. Burial of seed should be useful in some situations and could be incorporated into best practice procedures for councils and contractors that are required to conduct earthworks in infested areas. The top 20 cm of soil could be stockpiled then the relevant works conducted and the top soil returned to positions where it would be covered by at least 10 cm of clean soil. Field trials are underway to determine the practicality of these measures. Solarisation and microwave treatments would appear to be less likely contenders for successful techniques. Smoked water and many other organic compounds appear to be limited in their usefulness probably because the impermeable seed coat provides robust protection from outside agents in natural as well as artificial environments.

ACKNOWLEDGMENTS

Funding provided by the National Heritage Trust, Defeating the Weed Menace program and the Department of Agriculture and Food Western Australia is gratefully acknowledged. Thank you to Steve and George Franey and Ric Fenny for the use of their land and to Richard Hill from of Richard Hill & Associates, New Zealand for his helpful insights.

REFERENCES

Adkins, S. W. and Peters, N. C. B. (2001). Smoke derived from burnt vegetation stimulates germination of arable weeds. *Seed Science Research* 11, 213-222.

Hill, R. L., Gourlay, A. H., Lee, W. G., and Wilson, J. B. (1996). Dispersal of seeds under isolated gorse plants and the impact of seed-feeding insects. Proceedings of the Forty Ninth New Zealand Plant Protection Conference, Quality Hotel Rutherford, Nelson, New Zealand, 13-15 August, 1996. 114-118.

Ivens, G. W. (1983). The influence of temperature on germination of gorse (*Ulex europaeus* L.). *Weed Research* 23, 207-216.

Kudsk, P., Thonke, K. E., and Streibig, J. C. (1987). Method for assessing the influence of additives on the effect of foliar-applied herbicides. *Weed Research, UK* 27, 425-429.

Menges, R. M. and Wayland, J. R. (1974). UHF electromagnetic energy for weed control in vegetables. *Weed Science* 22, 584-590.

Moore, C. B. and Moore, J. H. (2005). HerbiGuide - The Pesticide Expert on a Disk. 20.2. Box 44, Albany, Western Australia, 6331

Moore, J.H. and Jettner, R. (2002). The effect of glyphosate, paraquat and diquat as a crop topping application on the germination of barley. Crop Updates 2002, Weeds Update Department of Agriculture Western Australia.

Puentes, M. A., Pereiras, J., and Casal, M. (1988). Study of the seedbank of *Ulex europaeus* L. shrublands in Galicia (NW Spain). I. First results. *Revue d'Ecologie et de Biologie du Sol* 25, 215-224.

Rolston, M. P. and Talbot, J. (1980). Soil temperatures and regrowth of gorse burnt after treatment with herbicides. *New Zealand Journal of Experimental Agriculture* 8, 55-61.

Scarsbrook, E. and Davis, D. E. (1971). Effect of sewage effluent on growth on five vascular aquatic species. *Hyacinth Control Journal* 9, 26-30.

Sixtus, C. R., Hill, G. D., and Scott, R. R. (2003). The effect of temperature and scarification method on gorse (*Ulex europaeus* L.) seed germination. *New Zealand Plant Protection, Volume 56, 2003.Proceedings of a conference, Chateau on the Park, Christchurch, New Zealand, 12-14 August 2003* 201-205.

Zabkiewicz, J. A. and Gaskin, R. E. (1978). Effect of fire on gorse seeds. *Proceedings of the 31st New Zealand Weed and Pest Control Conference.* 47-52.