Emergence and control of gorse seedlings after the 2017 Port Hills fire

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Abstract
An experiment on the Port Hills, Canterbury, after mature gorse was burnt in the fires of February 2017, showed an oversown Italian ryegrass mix out-competed the rapidly germinating gorse seedlings. The shaded gorse seedling population reached a peak of 680 plants/m^2 in June, declining to ~450 plants/m^2 in October compared with >600 plants/m^2 in the unshaded plots. As soil moisture dropped in summer, the gorse seedling population decreased to 10 plants/m^2 by March 2018, compared with 73 plants/m^2 in the unshaded plots. Gorse seedlings that had been shaded by Italian ryegrass had shorter roots and lower dry weights than those grown without competition. The oversown mix was more successful on the south than north-facing slope where more bare ground enabled patches of gorse to re-establish. The oversowing of Italian ryegrass was shown to be a viable option to control gorse particularly after an unplanned burn that removed the fences and water supply.

Keywords: aspect, Italian ryegrass, *Lolium multiflorum*, oversowing, *Ulex europaeus*

Introduction
On 13th February 2017, a major fire started in grasslands on the Port Hills near Christchurch. It ignited on Early Valley Road and swept uphill into the valley, burning vegetation and scattering livestock. A second fire started on Marleys Hill. Together they burnt 1645 ha of land, including a mature *Pinus radiata* forest, native bush, 11 houses, and two outbuildings. The major fuel source was dried-off seedheads and dead material from laxly grazed tall oat grass (*Arrhenatherum elatius*), browntop (*Agrostis capillaris*) and cocksfoot (*Dactylis glomerata*)-based pasture. This standing herbage of 5-6 t DM/ha had built up after a wet spring in 2016 that had encouraged pasture growth. This was followed by 3 months of below average rainfall (Figure 1) and warm, drying north-west winds. The resultant dry fuel covered thousands of hectares from Governors Bay to Tai Tapu. The steepness of the terrain made fighting the fire from the ground difficult so helicopters were used for protecting houses. Vegetation such as gullies of mature gorse (*Ulex europaeus*) burnt spectacularly and left a layer of ash covering the ground. These areas had no remaining ground cover and were, therefore, highly susceptible to erosion and ingress of weeds.

Land owners in Early Valley contacted Lincoln University for advice on how to regenerate the pastures and rapidly revegetate the bare gorse gullies before the onset of winter rainfall. Visual inspection in March confirmed that in pasture areas hundreds of subterranean clover (*Trifolium subterraneum*) seedlings had emerged from the burnt ground. Within days of the first post-fire rainfall, rhizomatous weeds such as Californian thistle (*Cirsium arvense*), yarrow (*Achillea millefolium*) and twitch (*Elymus repens*) emerged from the blackened earth. These were followed by recovery of cocksfoot and ryegrass (*Lolium perenne*) plants on the exposed grass slopes. Based on those observations, the decision was made not to oversow the pasture areas but to concentrate on controlling the regeneration of gorse in the gullies.

Burning is one of the easiest ways to remove mature gorse plants and is commonly used in forestry (MacCarter & Gaynor 1980). However, the heat from fire usually stimulates germination of gorse seeds present in the soil (Zabkiewicz & Gaskin 1978). This was apparent after the Port Hills fire where high populations of gorse seedlings quickly emerged from amongst the stumps of burnt mature gorse plants. Thus, the fire provided a unique opportunity for private land holders to control gorse. After the fire many of these lifestyle blocks had no fences, no water supply, and serious damage to houses with no immediate prospect of re-fencing. Thus, grazing stock could not be used as part of the gorse control solution.

Previous research has shown that gorse can be controlled as a seedling if it is out-competed for light (Moot *et al*. 2007). In glasshouse experiments, Ivens & Mlowe (1980) and Davies *et al.* (2005) showed that perennial ryegrass competition could decrease the dry weight of gorse seedlings. However, neither trial resulted in the death of gorse seedlings because of perennial ryegrass competition. Based on these results perennial and Italian ryegrass (*Lolium multiflorum*) were used in this experiment exploiting their rapid establishment in cool autumn conditions (Moot *et al.* 2000).

The first aim of this study was to quantify the number of gorse seedlings that had regenerated from under the

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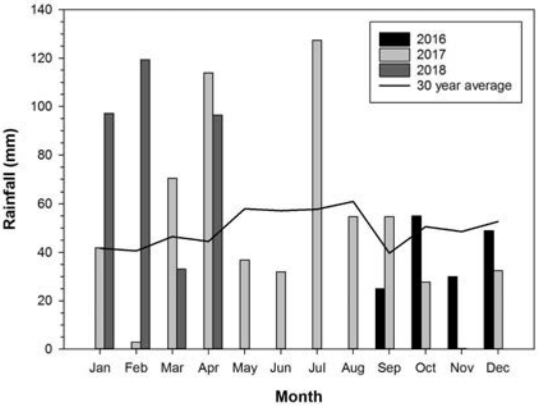

Figure 1 Monthly rainfall for 2016, 2017 and 2018, and a 30 year average for Broadfields, Lincoln, 9.5 km from the experimental site (NIWA 2018).

burnt gorse stand, and the second was to determine if oversown temperate pasture seeds could be used to decrease gorse seedling survival.

Methods

Site and climate

The experimental sites were located on a property off Early Valley Road on the Port Hills near Christchurch (43°37'S, 172°34'E) in a gully that had been burnt in the recent fires. This left a scorched and bare area with no ground cover on 10 hectares of a north and south-facing gully. Before the fire, the gully had been covered in mature gorse bushes for over 30 years. On the 17th March 2017, the area was oversown (using a drone helicopter) with a seed mixture containing the equivalent of 10 kg/ha Italian ryegrass, 5 kg/ha perennial ryegrass, 5 kg/ha subterranean clover and 2 kg/ha cocksfoot. Rainfall data for the area are presented in Figure 1.

Experiment 1: Gorse seedling control with oversown grass

To determine the effect of oversowing the pasture mix on gorse seedling emergence, eight paired plots (1.4 x 1.9 m) were marked across the south-facing hillside of the burnt gorse area. Before oversowing, a linen sheet was pegged out over one of each pair of the plots to prevent seed from falling on these areas. This created an oversown seeded plot and an unseeded control. Gorse seedlings were counted in 10 fixed 0.01 m^2 quadrats within each plot, every 2 weeks, between 28th March and 26th May 2017. After this, counts were taken every 3 to 4 weeks depending on weather conditions until 21st March 2018.

Experiment 2: Aspect and oversowing

In the burnt gorse area two 20 m transects were established on the hillside with a north aspect and two south-facing, both at similar altitudes. All gorse, subterranean clover and grass seedlings were counted within a 0.01 m^2 quadrat placed at 1 m intervals along the 20 m transect on the same dates as utilised for Experiment 1, until the 3rd October 2017.

Herbage mass was assessed in five 0.1 m^2 randomly placed quadrats on both the north- and south-facing slopes on 28th November 2017, to determine botanical composition and yield. A subsample of herbage was separated into ryegrass, cocksfoot, clover, gorse, dead and weeds and dried at 60°C for 72 h before weighing.

Experiment 3: Impact of Italian ryegrass shading

The dominant oversown species that emerged was Italian ryegrass. It is therefore referred to as the control agent in all experiments. To quantify the impact of Italian ryegrass shading on gorse seedling establishment, gorse seedlings were dug up on 7th December 2017 from five randomly selected areas of bare ground, where Italian ryegrass had not established, and shaded areas, where Italian ryegrass was the dominant vegetation cover, on both the north and south-facing slopes. Approximately 30 plants were dug up from each area. In heavily shaded areas there were few if any gorse seedlings present. Gorse plants were transported to the laboratory, where 10 randomly selected plants from each area were washed and root and shoot length were measured. Gorse plants were oven-dried for 6 days at 60°C and weighed in groups of 10 to get an average weight for shaded and unshaded areas on both the north and south-facing slopes. Roots were also checked for signs of nodulation.

Statistical analysis

Statistical analyses were preformed using GENSTAT 18. For Experiment 1, a two sample 't'-test was used to determine if there was a difference in the number of gorse seedlings in seeded and unseeded control plots established on the south-facing slope. For Experiment 2, a two sample 't'-test was also used to determine if there was a difference between the north- and south-facing slopes in gorse, grass and clover seedling establishment along the transects. For Experiment 3, a one way ANOVA was used to determine if there was a difference in gorse seedling dry weight and root and shoot lengths, between the shaded and unshaded plants sampled.

Results

Experiment 1: Gorse seedling control with oversown grass

In both treatments there were ~100 gorse seedlings/m^2 on 28th March 2017 (Figure 2). The number of gorse seedlings then increased to 680 plants/m^2 by 26th

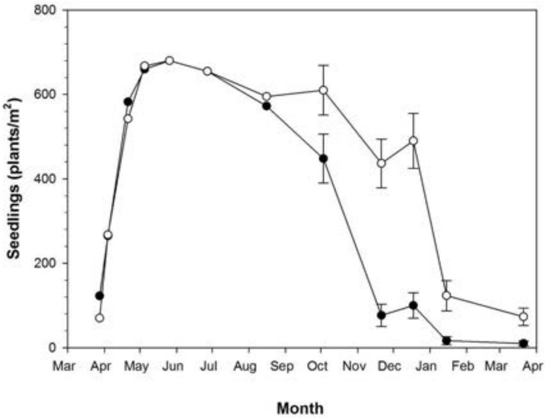

Figure 2 Number of gorse seedlings (plants/m^2) in plots with (●) or without (○) oversowing of pasture seed on a south-facing slope of a burnt gorse gully on Port Hills, Canterbury. Error bars represent the standard error of the mean.

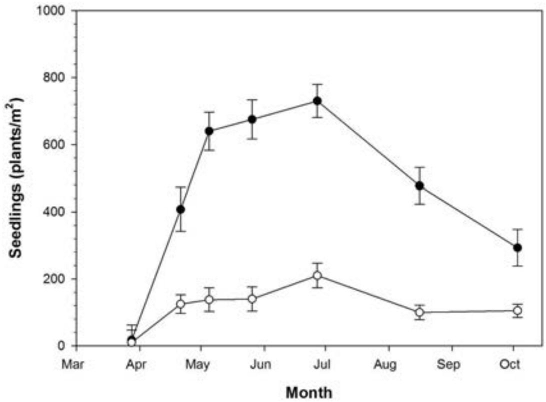

Figure 3 Number of gorse seedlings (plants/m^2) on north (○) and south (●) -facing slopes during 2017 after oversowing a burnt gorse gully on the Port Hills, Canterbury. Error bars represent the standard error of the mean.

May 2017. By late-June the number of gorse seedlings began to decline. On the 3rd October 2017 there were fewer (P<0.001) gorse seedlings in the sown plots (447 plants/m^2) than in the unsown control (610 plants/m^2), equating to a 52% reduction in gorse seedling density. The gorse seedling population continued to decline after October to <100 plants/m^2 in the sown plots compared with ~480 plants/m^2 (P<0.001) in the unsown controls, and by 15th January 2018 there were <20 plants/m^2 in the oversown plots and 120 plants/m^2 in the controls (P=0.007). There were further reductions to 10 and 73 plants/m^2 in the sown and unsown plots, respectively, by the final measurement on 21st March 2018 (P=0.006).

Experiment 2: Aspect and oversowing

The herbage cut on 28th November 2017 showed the dominant ground cover in spring after oversowing was Italian ryegrass (control agent). It represented 60% of the 8.5 t DM/ha yield on the north-facing slope and 73% of the 10.6 t DM/ha yield on the south-facing slope (Table 1). Perennial ryegrass was present, but to a lesser extent than the Italian ryegrass. There was no difference in gorse, weeds and dead material, which was mainly dead Italian ryegrass tillers, between the two aspects. The south side had more cocksfoot which made up 6.40% of the pasture compared with the north-facing slope where it was <3%. Subterranean clover showed the opposite trend with more on the north (6.71%) than south side (0.15%).

Similar numbers of gorse seedlings (P=0.420) were present on the south and north-facing slopes on 28th March 2017 (Figure 3). The number of gorse seedlings increased from fewer than 10 plants/m^2 on both slopes, with the increase being much higher on the south-facing slope. Three weeks later there were more (P<0.001) gorse seedlings on the south-facing slope (408 plants/m^2) than the north-facing slope (125 plants/m^2). This trend continued throughout the winter. Gorse seedlings reached their highest population for both slopes on the 27th June 2017, with more (P<0.001) gorse seedlings growing on the south (730 plants/m^2) than north-facing slope (210 seedlings/m^2). Gorse seedling populations then declined on both slopes, but the decline was more rapid on the south-facing slope. On the last measurement date, 3rd October 2017, there was 35% more (P<0.002) gorse seedlings on the south than north-facing slope.

Five weeks after oversowing, 340 Italian ryegrass seedlings/m^2 had emerged on the south-facing slope compared with 75 seedlings/m^2 (P<0.001) on the north-facing slope (Figure 4). From this point, the number of grass seedlings on the south-facing slope declined to ~200 plants/m^2 in June which was still ~150 plants/m^2 more (P<0.001) than on the north-facing slope, maintaining

Table 1 Yield and botanical composition of pasture sampled on north- and south-facing aspects on the 28th November 2017 after oversowing a burnt gorse gully on the Port Hills, Canterbury.

Aspect	Yield (kg DM/ha)	Botanical composition (% of DM)					
		Ryegrass	Cocksfoot	Clover	Gorse	Weeds	Dead
North	8500	60.2	0.28	6.71	0.86	12.4	19.5
South	10500	72.8	6.40	0.15	1.04	2.48	17.1
P value	0.074	0.074	0.015	0.001	0.734	0.150	0.410

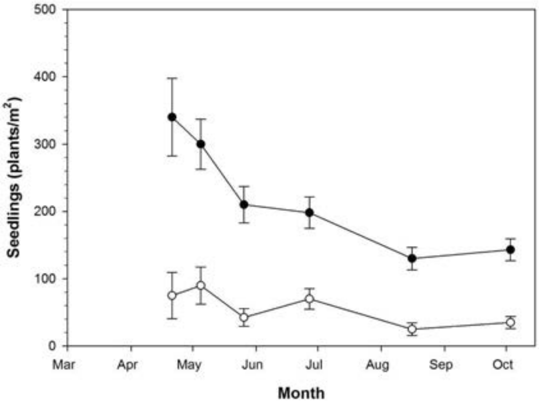

Figure 4 Number of Italian ryegrass seedlings (plants/m^2) on north (○) and south (●) -facing slopes during 2017 after oversowing a burnt gorse gully on the Port Hills, Canterbury. Error bars represent the standard error of the mean.

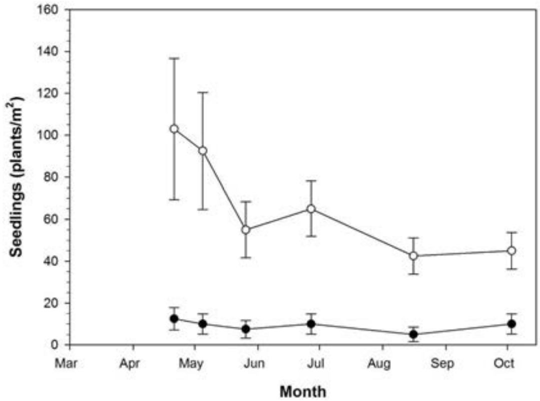

Figure 5 Number of subterranean clover seedlings (plants/m^2) on north (○) and south (●)-facing slopes during 2017 after oversowing a burnt gorse gully on the Port Hills, Canterbury. Error bars represent the standard error of the mean.

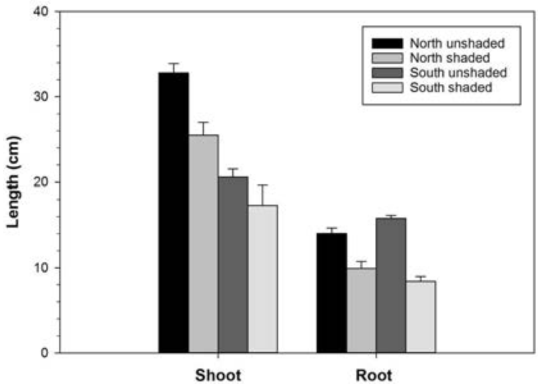

Figure 6 Shoot and root length of gorse seedlings grown with or without pasture shade on north and south-facing slopes on the 7th December 2017 after oversowing a burnt gorse gully on the Port Hills, Canterbury. Error bars represent the standard error.

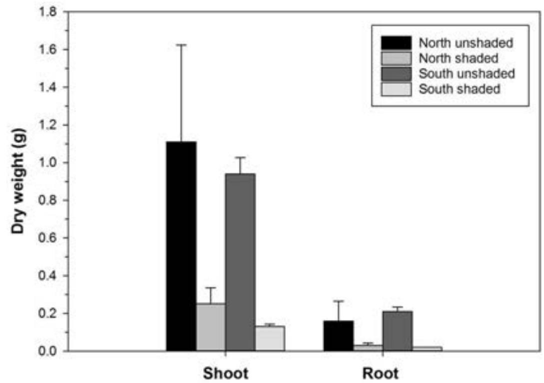

Figure 7 Shoot and root dry weight of gorse seedlings grown with or without pasture shade on north and south-facing slopes on the 7th December 2017 after oversowing a burnt gorse gully on the Port Hills, Canterbury.

these differences at the final measurement date.

The temporal pattern of establishment for subterranean clover was consistent with the grass, but populations were reversed with more subterranean clover seedlings emerged on the north-facing slope than the south-facing slope (Figure 5). At the first measurement there were ~100 subterranean clover seedlings/m^2 on the north-facing slope, but fewer (P<0.012) than 20 plants/m^2 on the south-facing slope. By October the numbers had declined to 45 plants/m^2 on the north-facing slope, still more (P<0.001) than the 5-15 plants/m^2 found on the south-facing slope at each measurement date.

Experiment 3: Impact of Italian ryegrass shading

Gorse seedlings on the unshaded north-facing slope were taller (averaging 32.8 cm) (P<0.001) than seedlings (20.6 cm) on the unshaded south-facing slope (Figure 6). Shaded gorse seedlings on both slopes were reduced (P<0.001) with those on the south-facing slope being the shortest at 17.3 cm.

Gorse seedlings growing in unshaded conditions had longer (P<0.001) roots than shaded gorse seedlings (Figure 6). On the south side, roots of unshaded seedlings (15.8 cm) were over double (P<0.001) the length of those grown under shade from Italian ryegrass.

When sampled on 7th December 2017, gorse seedlings grown on the north side with no shading had the highest (P=0.005) shoot dry weights of 1.11 g/plant (Figure 7). This was over four times heavier than shaded gorse seedlings. The shaded seedlings on the north side were taller than the unshaded seedlings on the south side (Figure 6), but unshaded seedlings were heavier as they were more mature and had begun to branch.

Unshaded seedlings also had higher (P=0.006) root dry weights than shaded seedlings (Figure 7). Visual observations confirmed that all gorse seedlings had roots that were nodulated, except a few small seedlings that appeared to be dying under the shaded treatments.

Discussion

One year after oversowing, shading from Italian ryegrass reduced the number of gorse seedlings to 10 plants/m^2 compared with >70 plants/m^2 in areas where there was no Italian ryegrass (Figure 2). The initial gorse seedling population in the unshaded plots shows the population potential created by the fire and indicates the rainfall conditions were conducive to survival of all seedlings had there been no intervention. The decline in seedling numbers in these control plots in November 2017 may have resulted from moisture stress due to a dry spring with only 83 mm rainfall compared with the average of 139 mm (Figure 1). In contrast, the oversown plots successfully controlled the gorse seedling populations that were reduced to 10 plants/m^2 by March 2018 (Figure 2).

The main period of gorse control appeared to occur in the spring after the autumn establishment and winter growth of the Italian ryegrass. This is shown by the lack of difference in the number of gorse seedlings between the shaded and unshaded control plots for up to 6 months after oversowing. The autumn sampling indicated continued germination of the gorse seedlings until a stable population occurred by May 2017. This remained at >550 seedlings/m^2 through winter. In October 2017 there was the first sign of population control via oversowing. The shaded plots had >400 plants/m^2 but this was 160 plants/m^2 fewer than the unseeded plots. However, by December 2017, there were still over 400 plants/m^2 in the control with fewer than 100 plants/m^2 in the shaded areas. This temporal pattern of decline was consistent with competition for light in the shaded plots. By spring 2017, the Italian ryegrass had produced a 40-50 cm tall canopy of 8-10 t DM/ha (Table 1) that completely over-topped the gorse seedlings. Previous research has shown that gorse seedlings are vulnerable to competition for light (Davies *et al.* 2005) and this method has previously been used to control them in ex-forestry land on the Canterbury Plains (Moot *et al*. 2007).

The suppression of the gorse population gave the land owner time to fix farm infrastructure and start grazing from November 2017, which was not possible immediately after the fire. However, in mature stands, a single bush may occupy a square metre so the potential still exists for the stand to re-establish from the population that remains in both the control and shaded areas.

Major reductions in the gorse population occurred in the shaded area through the summer as the site dried out. The Italian ryegrass would have assisted the rapid drying of the soil surface in spring, contributing to the death of gorse seedlings through moisture stress over summer. Gorse seedlings have a shorter and less extensive root system than ryegrass seedlings (Ivens & Mlowe 1980). This disadvantages them when competing with ryegrass for water and nutrients. Gorse seedlings that were shaded by ryegrass had shorter shoots and roots (Figure 6) and lower dry weights (Figure 7) than unshaded seedlings, resulting in less photosynthesis by the gorse seedlings, and therefore less total dry matter to partition to roots and shoots. Davies *et al.* (2005) found perennial ryegrass sown at 15 kg/ha significantly reduced gorse seedling shoot dry weight from around 23 g in the control to 2 g in the ryegrass treatments. Gorse seedlings that had been shaded were still soft and less mature in December 2017 compared with unshaded seedlings, as spine development in gorse is delayed in low intensity light (Bieneik & Millington 1968). This suggests the gorse seedlings in the pasture area will remain palatable to cattle and sheep for longer than in unshaded areas.

As expected, the oversowing in this experiment was inconsistent across the valley area. This resulted in areas of bare ground where Italian ryegrass competition was minimal and did not control the gorse seedlings. These areas either have to be resown or sprayed with appropriate herbicides to eliminate the remaining gorse seedlings.

Observations in March 2018, showed that no new gorse seedlings were germinating in areas of bare ground. This suggests that the majority of gorse seed in the seed bank germinated after the fire. Thus, the fire has provided an opportunity to eliminate gorse from the area providing that the remaining gorse seedlings are killed before they flower and further germination of seeds does not occur from the soil.

Higher populations of Italian ryegrass and gorse seedlings were found on the south-facing slope of the gully compared with the north-facing slope (Figures 3 and 4), likely due to the south-facing slopes having a higher soil moisture content (Radcliffe 1982) favouring initial establishment of the ryegrass. Similar results were found by White *et al.* (1972) who showed that oversown perennial ryegrass had better establishment by 6 months after sowing on the south-facing slope (21.3 plants/m^2) compared with the north-facing slope (4.7 plants/m^2).

In contrast, subterranean clover established in higher numbers on the north-facing slopes (Figure 5) which was consistent with previous studies (Power 2007). It seems likely that the lower establishment of Italian ryegrass seedlings on this drier slope allowed more bare ground for the subterranean clover to establish. Subterranean clover is known as a fast establishing species (Moot *et al.* 2000) and this was evident in the burnt pasture areas where over 600 seedlings/m^2 emerged within 4 days of the first autumn rainfall post-fire. Subterranean clover germinates and then forms a low growing rosette that is likely to be out-competed by the taller Italian ryegrass. It seems likely that the inclusion of the subterranean clover was not necessary for gorse seedling control in this situation. However, there were high subterranean clover populations in adjacent burnt pasture, but a lack of subterranean clover seed in the mature burnt gorse block. This suggests its introduction at the time of oversowing was prudent as the legume of choice for this environment, when permanent pasture development is the overall aim.

Conclusions

Italian ryegrass sown at 10 kg/ha effectively controlled gorse seedling regeneration on a burnt gorse block.

There was minimal establishment of other sown species but their impact should be assessed over time, particularly if the Italian ryegrass does not regenerate.

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