VEGETATION SUCCESSIONS OVER 30 YEARS OF HIGH COUNTRY GRASSLAND INVASION BY *PINUS CONTORTA*

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ABSTRACT

The invasion of a high country grassland site (850 m asl) by lodgepole or contorta pine (*Pinus contorta*, Dougl.) wildings was monitored over 32 years in the Craigieburn Range, Canterbury. The first wildings appeared in 1975. By 1985, density had reached 34,550 stems/ha, with a mean height of 1.85 m and a basal area of 17 m²/ha. By 2007, stocking had dropped to 11,400 stems/ha, with a mean top height of 14.3 m and a basal area of 104 m²/ha. Thirty-eight plant species were present 10 years after wilding invasion started. Twenty-six species (68%) were indigenous. By 2007, the number of species present had dropped to seven, none of which were indigenous. The introduced tussock hawkweed (*Hieracium lepidulum*) featured in both assessments. It was concluded that more species are likely to invade as the canopy opens up, but if native species are wanted they may have to be introduced by artificial seeding.

Keywords: *Pinus contorta*, natural regeneration, wilding tree, invasion, vegetation, successions.

INTRODUCTION

Hundreds of thousands of hectares are affected by the natural regeneration of introduced conifers in New Zealand (Hunter & Douglas 1988; Ledgard 2004). Lodgepole or contorta pine (*Pinus contorta*) is commonly recognised as the most vigorous invasive conifer, and although rarely planted today, remains the dominant species in many areas where wildings are a problem (Ledgard 2001). Like a number of pines, contorta is a pioneer species, which can quickly dominate invaded grasslands and open shrublands and forest. However, it is a light-demanding species that will not regenerate under its own canopy unless a major disturbance is involved. There is circumstantial evidence to suggest that more shade-tolerant species, including many native species, will invade under mature contorta stands, especially as they reach a later successional stage and start to 'open up' due to destabilising events such as strong winds and heavy snows. However, there are no long-standing studies to quantify this in New Zealand.

In the Hut Creek catchment of Craigieburn Forest Park in inland central Canterbury, the first contorta pine was planted in 1959 (Ledgard & Baker 1988), and was recorded as spreading in the mid-1970s. In 1980, a 200 m² plot was established in grassland immediately alongside a stand of contorta pine planted in 1961, to monitor the invasion of wildings, and their effects on the resident vegetation. Assessments were carried out until 1985 when they ceased due to a shift in direction of research resources. Fortunately, the plot pegs, tree tags and measurement records survived over the next 22 years, so that a complete remeasurement was possible in 2007. This paper describes the vegetation changes that have taken place between 1980 and 2007.

METHODS

Trial site

The trial is situated in Hut Creek (NZ Topographic Map 260 K34, E 0550, N 8330), a small tributary of Cave Stream, which flows into Broken River before reaching the

Waimakariri River. It is on a 22° slope with a south-westerly aspect at an altitude of 850 m asl. Being close to the valley floor, it is reasonably sheltered, but can be reached by the prevailing strong north-west winds, which would blow seed directly from the adjacent parent stand into the trial block. The original mountain beech (*Nothofagus solandri* var. *cliffortioides*) forest cover was removed by burning in the mid 1800s. Subsequent grazing and burning until the early 1960s resulted in a degraded fescue grassland with large patches of subsoil where the topsoil had been eroded away. The Acidic Allophanic Brown soil (Hewitt 1992) is classified as a member of the Tekoa set (NZ Dept of Scientific and Industrial Research 1968). Temperatures are mild (mean summer 13.9°C, mean winter 2.0°C), with adequate rainfall (1450 mm) spread evenly throughout the year. Ground frosts have been recorded around 150 days annually, and can occur at any time during the growing season (Ledgard & Baker 1988).

Measurements

The study block is rectangular, measuring 20 x 10 m, with the northern boundary running between 4–6 m from the edge of the parent seed stand. The block is divided into one hundred 2.0 m x 1.0 m plots, arranged in ten 20 m rows across the slope. At the first assessment in 1980 (5 years after the first wildings arrived), all contorta pine seedlings were number tagged, measured for height and their age (and hence year of arrival) determined by counting the number of branch whorls. Further assessments of tree numbers, ages, diameters at breast height (diameter) and heights were made annually at the end of all growing seasons until (and including) 1985, with every new seedling being tagged. After 1985, the next measurement was in 2007.

Vegetation transects (20 m long) were laid out across the trial area along plot rows 2, 4, 6, 8 and 10. Changes in vegetation were monitored using frequency counts (Allen et al. 1983) inside 15 cm diameter rings spaced at 40 cm intervals along the transects. These assessments were carried out in 1980, 1981, 1984, 1985 and 2007.

RESULTS

Number, basal area and height of contorta pine trees

The number of contorta pine stems increased from 500/ha in 1975 to 34,550/ha in 1985 (Fig. 1). At this time, 10 years after the first wilding arrival, the total number of pines on the sites was starting to level out and by 2007, when assessments were resumed, the number had dropped to 11,400 stems/ha.

FIGURE 1: Number of contorta pine stems per hectare from 1975 to 2007.

The basal area of live contorta pine trees in 1985 had reached 17.4 m²/ha, and between 1985 and 2007 it increased to 104.0 m²/ha at a mean rate of 3.95 m²/ha/year (Fig. 2). In the years 1982 to 1985 the mean annual basal area increase was higher, at 4.8 m²/ha/year.

FIGURE 2: Mean basal area of live contorta pine trees from 1982 to 2007.

The mean height of contorta pine trees in 1980 had reached 48 cm. The mean height of the trees increased at an almost constant rate from 1980 to 1985, when the mean height was just under 200 cm (Fig. 3). Between 1985 and 2007, many trees were damaged and malformed by snow and wind events. In 2007, the mean height of intact (undamaged) trees was 620 cm. Of the intact trees, the mean top height of the 100 largest diameter trees was 1,430 cm.

FIGURE 3: Mean height of intact (not damaged) contorta pine trees from 1980 to 2007.

Stem damage

The percentage of damaged trees was low between 1980 and 1985 (< 1%), but as the trees matured, dense stocking led to dead tops (mostly in smaller trees) and thin spindly stems, which were very susceptible to damage by wind and, particularly, snow. In 2007, 37% of the trees had dead tops or had bent stems and/or had their tops broken. Most of these were in the smaller diameter classes.

Vegetation

Between 1975 and 1985 the numbers of contorta pine seedlings increased rapidly, but the canopy remained sufficiently open to allow a range of native and introduced plant species to persist. Thirty-eight plant species were found in the study plot in 1981. The most common species are listed in Table 1.

The species composition up until 1985 was characterised by grasses (mostly introduced) and native herb species. However, with the increasing establishment and growth of pines, the less shade-tolerant native species were suppressed and disappeared, so that in 2007 the ground cover contained only five exotic vascular species plus a moss and a lichen (Table 1).

Grasses, like sweet vernal (*Anthoxanthum odoratum*) and *Festuca novae-zealandiae*, were abundant in 1980 but decreased quite rapidly up until regular assessments ceased in 1985. On the other hand, the frequency of another grass, browntop (*Agrostis capillaris*) increased slightly during this period as did the fern *Blechnum penna-marina*, but overall most species either maintained or decreased their frequency as pine dominance rose. The two hawkweeds (*H. lepidulum* and *H. praealtum*) maintained their cover until 1985, and in 2007 were the only species that remained from the original ground cover vegetation, although with much reduced frequency. The only other species present in 2007, besides the two *Hieracium* species, were two tree species, Douglas-fir (*Pseudotsuga menziesii*) and rowan (*Sorbus aucuparia*), and the grass, Yorkshire fog (*Holcus lanatus*).

DISCUSSION

Development of the *P. contorta* stand

The combination of ample seed, together with an existing sparse ground cover on the trial site, led to a rapid increase in contorta seedlings between 1975 and 1985. A study of seedling ages indicates that the peak period of establishment occurred in 1977 and 1978. By 1980, 5 years after invasion began, the establishment of new contorta pine seedlings was already slowing down. It appears that pines that had established earlier had already filled most of the potential seedling sites. By 1985, seedling density had reached 34,550 stems/ha. Although this might appear high, densities of young *P. contorta* seedlings regenerating in the American north-west after fire have been recorded at well over 100,000 stems/ha (Lotan & Perry 1983). In 2007 at Craigieburn, inter-tree competition had led to a 33% drop in stocking, down to 11,400 stems/ha, whilst basal area had climbed from under 5 m²/ha to 104 m²/ha. As expected, the majority of this basal area (70%) was held in the larger trees, even though they represented only 17% of the total number of stems. The 2007 basal area is similar to the basal area recorded (94 m²/ha) in plots of similar aged contorta pine located in a planted stand 100 m away from the present trial (A. Nordmeyer, pers. comm.).

A feature of the study area in 2007 was the high number of trees with broken tops and bent stems – many were bent over 90° from around 2 m above ground level. Thirty-seven percent of trees were in this damage category, the majority being in the middle size classes. The major cause appeared to be heavy winter snows. Alongside, in the older ‘parent’ stand, planted in 1961 at around 1.5 x 1.5 m spacings (4,444 stems/ha) and still standing at 4,200 stems/ha, the level of damage was significantly less, as the even spacing had allowed stems to grow to larger diameters and they were therefore more stable. As a result of the high number of trees with broken tops and bent stems in the naturally regenerated trial site, light levels at ground surface appeared to have increased significantly, which is likely to accelerate vegetation successions in the near future.

Vegetation changes

The main purpose of this trial was to monitor the invasion of high country grassland by contorta pine wildings, and the effect of conifer cover on the succession of other species over time. It is well known that vigorous introduced conifers can quickly suppress lower stature resident native species (Hunter & Douglas 1984; Ledgard 1988), and in this trial the number of different species present between the early years (before major suppression occurred) and 2007, dropped from thirty-eight to just seven. Of the thirty-eight species

TABLE 1: Species frequency (% occurrence in all 250 frequency plots) of the most common species from 1980 to 2007 (* indicates native species).

Species	1980	1981	1984	1985	2007
Grasses					
<i>Agropyron scabrum</i> *	0	0.4	1.6	0.4	0
<i>Agrostis capillaris</i>	15.6	1.6	25.6	32.4	0
<i>Anthoxanthum odoratum</i>	38.4	38.4	23.2	5.2	0
<i>Carex</i> sp.*	0	0.4	0	0.4	0
<i>Festuca matthewsii</i> *	0	0	3.6	0.8	0
<i>Festuca novae-zelandiae</i> *	7.6	6.4	0	1.2	0
<i>Holcus lanatus</i>	0	0.4	0	0	0.4
<i>Luzula rufa</i> *	0	0.4	0.8	0	0
<i>Luzula</i> sp.*	2.8	1.6	0	0	0
<i>Poa caespitosa</i> *	0.8	1.2	0	0	0
<i>Poa colensoi</i> *	10	11.2	10.4	11.6	0
<i>Poa pratense</i>	0	0	0.4	1.2	0
<i>Rytidosperma semiannularis</i> *	0	0	0	0.4	0
<i>Rytidosperma setifolia</i> *	0	2	0	0	0
<i>Rytidosperma unarede</i> *	0.8	0	0.4	0	0
Herbs					
<i>Acaena</i> sp.*	4.8	5.6	4.4	3.2	0
<i>Anisotome aromatica</i> *	7.2	8.8	6.4	6	0
<i>Anisotome filiforme</i> *	2	6	0.4	0	0
<i>Celmisia gracilentia</i> *	0	0.8	0.4	0	0
<i>Celmisia spectabilis</i> *	0.8	0.4	0.4	0.4	0
<i>Crepis capillaris</i>	0.4	0.4	0.4	0.8	0
<i>Epilobium</i> sp.*	1.6	2	3.2	0.4	0
<i>Helichrysum bellidioides</i> *	0.4	1.2	0.8	0	0
<i>Hieracium lepidulum</i>	38	44	40.8	44.4	14
<i>Hieracium praealtum</i>	4.4	4	4	0	2.8
<i>Hypochoeris radicata</i>	1.2	0.8	0.4	0	0
<i>Mycelis muralis</i>	0	0	0	2.8	0
<i>Nertera</i> sp.*	0	0.8	0	0	0
<i>Ranunculus</i> sp.	0	2.8	0	0	0
<i>Raoulia subulata</i> *	4.4	0.4	0	0	0
<i>Senecio lagopus</i> *	1.6	2	2.4	0.8	0
<i>Trifolium repens</i>	0	0	0.4	0	0
<i>Viola cunninghamii</i> *	9.6	15.6	6.4	1.6	0
<i>Wahlenbergia albomarginata</i> *	6.8	13.2	6.4	3.6	0
Shrubs					
<i>Dracopylum procumbens</i> *	1.2	0.8	1.2	0.8	0
<i>Gaultheria depressa</i> *	12.8	14.4	9.6	7.2	0
<i>Hebe</i> sp.*	0	0	0	0.4	0
<i>Leucopogon fraseri</i> *	0	0.4	0.4	0	0
<i>Oreomyrrhis ramosa</i> *	0	0.4	1.6	0	0
<i>Ozothamnus</i> sp.*	0.8	0.4	0	0	0
<i>Pentachondra pumila</i> *	0	0.4	0	0	0
<i>Pimelia prostrata</i> *	0.4	0.8	1.6	1.2	0
Trees					
<i>Pinus contorta</i>	3.2	2	4	2.4	0
<i>Pseudotsuga menziesii</i>	0	0	0	0	1.2
<i>Sorbus aucuparia</i>	0	0	0	0	0.8
Ferns, mosses, lichens					
<i>Blechnum penna-marina</i> *	28.4	40.8	46.4	50.4	0
<i>Lichen</i> sp.	1.2	0	0	0	0.8
Moss	10.8	9.6	2	3.2	5.2
<i>Peltigera</i> sp. (lichen)	0	0	0	0	0.4

present initially, twenty-six (68%) were indigenous. Amongst the top ten most frequently occurring species prior to 1985 were seven native species, but only one of these, a fern (*B. penna-marina*), occurred consistently in the top three. The most frequent introduced species were the hawkweed, *H. lepidulum*, and two grasses, sweet vernal and browntop. By 2007, no native species could be found in the trial area, and from all the 1985 top ten species, just two remained – *H. lepidulum* and *H. praealtum* – the former with a much reduced frequency. *Hieracium lepidulum* can be the most persistent invasive species under beech forests (Wiser et al. 1998). It was present throughout the 23 years of that author's study, and its occurrence in plots increased over that time. Therefore, it may have been continuously present in the Craigieburn study plot between 1985 and 2007. Two new species in 2007 were the introduced trees, Douglas-fir and rowan, both of which are present locally as mature trees. Despite an abundance of local seed, no young contorta pine seedlings were located, most likely because this species is shade-intolerant, requiring at least 40% of full sunlight to grow sufficiently vigorously to form a climax canopy (Lotan & Perry 1983).

Within its North American home range, contorta pine stands are often colonised by more shade tolerant species as the canopy opens up and light levels increase (Lotan & Perry 1983). This should also be the case in New Zealand, as long as there is a seed source present. There are a number of native species that can establish and grow well under introduced pine canopies, in light levels that are not high enough for pine seedlings to flourish (Allen et al. 1995). However, such colonisation may take some decades. McQueen (1993) reported that 40-50 year old contorta pine on the south side of Mt Ruapehu were dense and dark beneath, with no growth under them, indigenous or naturalised. However, during an earlier visit to the same area in 1988, one of the present authors (N.J. Ledgard) noted a range of native species (including red and mountain beech saplings up to 3 m high) growing well under planted 60-year-old contorta pine stands. In addition, dense 30-40 year naturally regenerated wilding stands were starting to open up, under which a native understory was observed to be developing. There are a number of good examples of native understories growing under mature planted radiata pine stands – recorded by Henry (1954), McQueen (1961, 1993), Ogden et al. (1997), Allen et al. (1995) and Brockerhoff et al. (2003).

In the present study area at Craigieburn, 30 years after the first contorta pine seedlings established in grasslands adjacent to 14-16 year old planted stands, virtually all the initial resident ground vegetation has been suppressed and disappeared. However, there are signs that the canopy is now opening up sufficiently to offer opportunities for more shade-tolerant species to establish from seed. Apart from the two hawkweeds (*H. lepidulum* and *H. praealtum*), the former of which is known to persist in poor light (Wiser et al. 1998), two introduced woody species, Douglas-fir and rowan, were also recorded as small seedlings (<5 cm tall). Unless the canopy opens up further, and light levels increase considerably, it is doubtful if the Douglas-fir will persist, as the species requires 30-45% of full sunlight to grow vigorously (O'Hara 2002). There are many instances in New Zealand where young seedlings under intact canopies have not persisted to compete at canopy level (Ledgard 2002). Parent trees of both the Douglas-fir and rowan are present locally, and the seed is readily spread some distance by wind and birds respectively. Also present nearby is the native mountain beech, the seed of which is spread by wind, but it is not blown far (Wardle 1984), which may explain its absence. Other native species associated with the Craigieburn beech forest understory, such as broadleaf (*Griselinia littoralis*) and small-leaved *Coprosma* spp., are sparsely represented locally and a lack of readily available seed may hinder their wider spread.

Since the study site lies in an area administered by the Department of Conservation, the most desirable successional outcome would be the establishment of indigenous species, which would eventually lead to a climax native vegetation. At Craigieburn, this would be mountain beech forest. Mountain beech seedlings have been successfully established under pine canopies in the Craigieburn area (Ledgard & Baker 1988), and some natural regeneration is already present under a contorta pine stand planted closer to a mountain beech margin. However, for such a succession to occur within the study area, beech seed may need to be artificially introduced, as it does not appear to be arriving naturally.

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