SHOOT GROWTH STUDIES OF PINUS CONTORTA, PINUS MUGO, AND LARIX DECIDUA IN THE KAWEKA RANGE

A. Cunningham and Q. W. Roberts*

SYNOPSIS

Growth rates of Pinus contorta, P. mugo, and Larix decidua were studied on six widely varying sites between 1,035 m and 1,465 m in the Kaweka Range in 1967-8 and 1968-9. The two growing seasons differed considerably in terms of mean monthly temperature, and this affected timing of the growth curve. Variability of growth between individual trees was greatest in P. contorta, least in L. decidua. At 1,035 m the active period of growth is spread over three months in P. contorta, and about two months in P. mugo and L. decidua. In general, high-altitude sites tend to delay initiation of the growth period, and erosion surfaces tend to advance it. Total annual growth is severely restricted on erosion surfaces, particularly at high altitudes.

INTRODUCTION

In the northern hemisphere, most annual height increment on conifers occurs during spring or early summer, and the cumulative growth plotted against time forms a sigmoid curve. Such a growth curve is for any given species similar from year to year, but there are considerable differences between species in the form and timing of the growth curve. In mountainland reforestation, it is important to have some understanding of growth curves for the species being used, and of the relationship between growth curves and climate.

Although seasonal growth curves have been documented by many overseas writers, there have been surprisingly few such studies in New Zealand. P. Wardle (1963) gave a general account of the annual growth cycle in representative subalpine shrubs and trees, which indicated distinct seasonal growth. Bussell (1968) explored the relationship between temperature and growth in several indigenous trees by comparison with the introduced Acer pseudoplatanus, and found in the mechanism controlling dormancy some differences between Acer and the southern hemisphere trees. Jackson (1969) found that Pinus radiata at 469 m altitude in central North Island grew almost continuously throughout the year. J. Wardle (1970) examined Nothofagus solandri at various altitudes from 45 to 1,340 m and illustrated that the period of active growth was greatly reduced at higher altitudes.

*New Zealand Forest Service, Napier.
This paper describes growth curves for three conifers which are important species in the reforestation of mountain-lands — *Pinus contorta*, *Pinus mugo*, and *Larix decidua*. The study was made between 1967 and 1969, on trees which had been planted about 8 years previously.

**SITES**

The trees studied were planted as part of a species trial programme on six different sites between 1,035 m and 1,456 m in the Kaweka Range (see Figs. 1 and 2). Fifty trees raised from seed of New Zealand origin were planted 1.2 m apart on each site in 1960. Of the six sites, four comprise different types of erosion surface, at different altitudes. The remaining two sites (1 and 5) have a vegetation cover and are included as non-eroding "controls", one at each end of the altitudinal range. Details of the sites are as follows:

**Site 1** (Manuka control, 1,035 m). Vegetation cover of manuka (*Leptospermum scoparium*) up to 2 m tall, with associated native plants. Soil A horizon almost completely intact. Slope 5 degrees.

**Site 2** (Bare pumice surface, 1,035 m). No vegetation. Soil A horizon absent, leaving B horizon exposed as smooth, bare surfaces of compact pumice. Slope about 30 degrees. This site is extremely infertile and the surface is regularly and rapidly eroded by wind, rain, and frost.

**Site 3** (Erosion pavement, 1,035 m). Very sparse vegetation. A and B horizons largely removed leaving an erosion pavement of greywacke boulders and fine stones. Slope about 15 degrees.

**Site 4** (Scree, 1,097 m). Bare scree, no vegetation. Loose rock particles mixed with varying degrees of fine rock or pumice forming a shallow layer over shattered greywacke substratum. Slope 30 to 35 degrees.

**Site 5** (Subalpine control, 1,463 m). Vegetation cover comprises subalpine plants up to 1 m tall, dominated by *Chionochloa pallens*. Soil A and B horizons more or less intact, not recently influenced by erosion. Slope about 38 degrees.

**Site 6** (Scree, 1,433 m). Bare scree, no vegetation. Loose rock particles with very little fine material. Slope 35 degrees.

**CLIMATE**

There are two meteorological stations in the study area, at 975 m (Makahu Saddle) and 1,463 m (Makahu Spur). General features of the climate at these stations are:

<table>
<thead>
<tr>
<th></th>
<th>Makahu Saddle</th>
<th>Makahu Spur</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean annual rainfall</td>
<td>2,870 mm</td>
<td>3,302 mm</td>
</tr>
<tr>
<td>Mean annual temperature</td>
<td>8.6°C</td>
<td>6.3°C</td>
</tr>
<tr>
<td>Mean daily wind</td>
<td>344 km</td>
<td>409 km</td>
</tr>
<tr>
<td>Observation period</td>
<td>1960-70</td>
<td>1969-70</td>
</tr>
</tbody>
</table>
Fig. 1: Location of study area.
In this region the growing season extends from September to April. The 1967-8 growing season was, with the exception of January, considerably warmer than the 1968-9 season. This is illustrated by the following figures showing mean monthly temperature (°C) at Makahu Saddle:

**FIG. 2:** Vertical photograph of study area showing location of sites.
The spring of 1968-9 was thus 1\frac{1}{2} to 2°C cooler than the previous year, and this delayed growth by 1 to 2 weeks.

SAMPLING AND MEASUREMENT

During the first growing season, 10 trees of each species were measured on each site. Selection was subjective, health and the possession of a suitable leading shoot being the main criteria used. As the season advanced, it was found that, on sites 4, 5, and 6, the shoot being studied was sometimes storm-damaged to the extent that measurements could not be continued. After the first growing season, the data were subjected to analysis of variance to determine whether the sample of 10 trees was sufficient. It was found that, for sites 1, 2, and 3, 10 trees were adequate, but that for the three high-altitude sites 15 trees would be preferable. This rate of sampling was adopted for the 1968-9 season, and tree selection was on a random instead of a subjective basis.

Measurements were made from the axil of a suitable lateral branch shortly below the resting bud, to the tip of the bud in the case of pines, and to the distal part of the leaf system in larch. During the first season, measurements were made once each week throughout the whole period of growth. In the second season, weekly measurements were made until growth had clearly commenced; thereafter measurements were made at intervals of two weeks. In the case of death or damage of a terminal shoot, no further measurement of that tree was made. Data analysis included plotting increment against time for each species on each site. A summary of the growth data is presented in Table 1.

RESULTS AND DISCUSSION

(a) Variability of Growth Curves by Individuals and by Species

Kozlowski and Ward (1961) point out that in some tree species there is considerable variation amongst individual growth curves, while in other species only slight variation occurs amongst individuals. Walters and Soos (1963) also examined individual variation in growth, and commented that much of the variation was due to differences in age and size of the trees. In the present study, variability amongst individual trees was examined on Site 1, as this is the site most closely comparable with those of other writers. Variability due to differences in age and size has been largely eliminated, as all sample trees were the same age, closely similar in size, and measurements were confined to leading shoots. Larix decidua shows the greatest uniformity of growth amongst individual plants, while P. contorta is the most variable. Most of the seasonal growth in these species is achieved within two or three months, a phenomenon which is aptly referred
### TABLE 1: AVERAGE MONTHLY GROWTH INCREMENT IN MILLIMETRES DURING TWO GROWING SEASONS ON EACH OF THE SIX SITES

| Site: | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| Sep.  | 12| 12| 10| 0 | 0 | 0 | 7 | 3 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Oct.  | 42| 41| 32| 16| 5 | 3 | 29| 21| 26| 17| 4 | 6 | 3 | 8 | 5 | 2 | 1 | 1 |
| Nov.  | 163| 97| 112| 51| 25| 11| 107| 47| 63| 52| 23| 17| 6 | 7 | 3 | 5 | 2 | 2 |
| Dec.  | 228| 109| 155| 49| 78| 31| 103| 44| 56| 55| 52| 23| 75| 9 | 31| 23| 2 | 5 |
| Jan.  | 127| 49| 92| 13| 75| 17| 18 | 11| 15| 19| 34| 11| 155| 30| 57| 34| 9 | 3 |
| Feb.  | 41 | 15| 23 | 4 | 22| 7 | 8 | 12| 6 | 5 | 5 | 5 | 5 | 110| 24| 32| 4 | 8 | 0 |
| Mar.  | 18 | 10| 16 | 2 | 11| 6 | 7 | 3 | 7 | 7 | 6 | 8 | 42 | 6 | 2 | 0 | 15| 0 |
| Apr.  | 2  | 2 | 4  | 0 | 2 | 1 | 4 | 1 | 5 | 5 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 |
to by Walters and Soos (1963) as the “grand” period of growth. During this time the growing tissues are particularly sensitive to damage from unseasonal low temperature storms or desiccating winds.

In Fig. 3, the monthly growth data from each tree on Site 1 have been converted to percentage total cumulative growth to illustrate more clearly the growth form patterns, and it
can be seen that in 1968-9 most of the *P. mugo* growth had been completed by the end of December, *P. contorta* by the end of January, and *Larix decidua* by the end of February. It will also be seen that, whereas the grand period of growth for *L. decidua* and *P. mugo* was of about two months' duration, it extended over three months in the case of *P. contorta*. In considering this, it should be borne in mind that the total growth increment in *P. contorta* is much greater than in the other two species. Although the grand period of growth for *L. decidua* is about six weeks later than the two *Pinus* species, it must be remembered that in larch the leaves grow to full size before any appreciable growth of the shoot occurs.

(b) *Growth Curves Related to Variation in Seasonal Temperature*

The cooler 1968-9 season was reflected by a delay, in all species, of one to three weeks in the grand period of growth (based on the time when 50% of the total annual growth had been achieved). It appears that on the harsher sites seasonal differences may be more pronounced. For example, on Site 1 (manuka, 1,035 m), *P. contorta* and *P. mugo* were delayed by 10 or 12 days, whereas on Site 3 (erosion pavement at the same elevation) the delay was increased to 15 or 18 days. At the highest altitude (Site 5, 1,463 m) the difference was 19 to 22 days. The pattern for *L. decidua* is similar.

(c) *Influence of Site on the Growth Pattern*

Timing of the growth curve is influenced by site in all three species, particularly *Larix decidua*, and least in *Pinus mugo*. The tendency is for a delay in development of the growth curve at higher altitudes. Comparing the two controls, Site 1 (1,035 m) and Site 5 (1,463 m), when 50% of the total annual growth has been reached, growth on Site 5 lags behind that on Site 1 by about 24 days in the case of *P. contorta*, 30 days in *P. mugo*, and 12 days in *L. decidua*.

In each species there are only slight differences between growth curves on Sites 1, 2, and 3 (all at 1,035 m). Timing of the growth curve seems to be advanced on scree sites, for example in all species growth on the high altitude scree (Site 6) occurs in advance of that on the corresponding high-altitude control (Site 5). A similar relationship occurs between sites 4 and 1.

Timing and development of the grand period of growth in trees is influenced by various factors, particularly temperature and solar radiation (Boyer, 1970). We have already indicated a relationship between the timing of growth curves and mean monthly air temperature. It is probable, however, that timing of the grand period of growth is also related to soil temperature, particularly during the period of active root growth which precedes shoot growth. A relationship between soil temperature and consequent shoot growth may help to explain the tendency for plant growth on erosion surfaces to occur a little ahead of that on adjacent sites where the trees
are growing on intact soils, assuming that the spring increase in soil temperature is more rapid on erosion surfaces.

(d) Influence of Site on Amount of Growth

Table 1 presents average monthly shoot growth on each site, and these data are illustrated in Fig. 4. Mean annual growth is given in Table 2.

![Graphs of monthly shoot growth increment for different sites](image-url)

**Fig. 4:** Monthly shoot growth increment; average of two growing seasons.
TABLE 2: MEAN ANNUAL GROWTH PER PLANT IN MM, AVERAGE FOR BOTH SEASONS, BY SITE

<table>
<thead>
<tr>
<th>Site</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>P. contorta</em></td>
<td>...</td>
<td>...</td>
<td>627</td>
<td>327</td>
<td>440</td>
<td>135</td>
</tr>
<tr>
<td><em>P. mugo</em></td>
<td>...</td>
<td>...</td>
<td>279</td>
<td>141</td>
<td>183</td>
<td>160</td>
</tr>
<tr>
<td><em>L. decidua</em></td>
<td>...</td>
<td>...</td>
<td>329</td>
<td>94</td>
<td>126</td>
<td>54</td>
</tr>
</tbody>
</table>

Total annual growth is clearly reduced at higher altitudes. Of the control sites, growth on Site 5 (1,463 m) is less than half of that on Site 1 (1,035 m). Similarly, on the erosion sites growth on Site 6 (1,433 m) is less than growth on Site 4 (1,097 m) which is less than growth on Sites 2 and 3 (1,035 m).

Total annual growth is also reduced on erosion surfaces. Growth values are much lower on Sites 2 and 3 than on the non-eroding counterpart Site 1. Similarly, growth rates on Sites 4 and 6 are less than on the non-eroding Site 5. Figure 4 illustrates the severe restriction placed on growth rates by a combination of altitude and erosion surfaces.

ACKNOWLEDGEMENTS

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REFERENCES


