

*Populus maximowiczii* 'NZ73011078' × *P. nigra* 'Blanc de Garonne'  
experimental clone wide-spaced trial 1999-2001

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Executive summary

Wide-spaced trials were established in 1999, 2000 and 2001 in different climatic zones to evaluate four *Populus maximowiczii* × *P. nigra* experimental clones. Trials were located at Parakai in Northland, Mapiu in the central North Island, Rissington in Hawke's Bay, Ashhurst in Manawatu, Windwhistle in inland Canterbury and at Miller's Flat in Central Otago. Six commercial clones were planted with the experimental clones to compare performance. Survival, height and diameter at breast height were measured to assess relative performance. The four experimental clones were NZ93-005-002 (blue/red), NZ93-005-007 (blue/brown), NZ93-005-009 (blue/green) and NZ93-005-010 (blue/orange). The clones are referred to by their colour code in the rest of the report.

Of the four experimental clones trialled, blue/green is recommended to be released for commercial use across all climatic zones in New Zealand, blue/brown could be considered for release for use in climatic zones with regular summer rain or on lower slopes where water stress will be lower, blue/orange should be released for use across all climatic zones, and blue/red could be considered for further trials in particular local environments or for use where lower vigour would be an advantage.

## Introduction

The genus *Populus* is distributed throughout the temperate zone of the Northern Hemisphere where some 30 species are known. Because of the easy hybridisation between the species, many spontaneous hybrid poplars have arisen; many more have been produced by artificial hybridisation. These hybrid poplars are not further propagated by seed, but vegetatively by cuttings. Throughout the world there are literally thousands of such poplar clones under test, while many hundreds of selected clones are already used in commercial plantings.

Poplars are not native to New Zealand and the first introductions were made between 1840 and 1850 during the early days of European settlement. The Lombardy poplar (*Populus nigra* 'Italica') and the American cottonwood (*P. deltoides* 'Virginiana') were the earliest introductions.

Since 1950, when the number of poplars planted for soil conservation and erosion control increased rapidly and their timber potential became better appreciated, a large number of selected clones have been introduced from Europe, America, Japan and China. A collection of over 200 poplar clones are now maintained for research and breeding purposes. Experimental crosses are carried out to develop clones more suitable for niche environments and purposes, and to future proof the country against new pests and diseases and changing climate.

Like many international poplar breeding programmes New Zealand's programme has depended on contestable government funding. This has meant that there have been periods of both high and low breeding activities.

New Zealand's climate is complex and varies from warm subtropical in the far north to cool temperate climates in the far south, with severe alpine conditions in the mountainous areas.

Mountain chains extending the length of New Zealand provide a barrier for the prevailing westerly winds, dividing the country into dramatically different climate regions. The West Coast of the South Island is the wettest area of New Zealand, whereas the area to the east of the mountains, just over 100 km away, is the driest.

Most areas of New Zealand have between 600 and 1600 mm of rainfall, spread throughout the year with a dry period during the summer. Over the northern and central areas of New Zealand more rainfall falls in winter than in summer, whereas for much of the southern part of New Zealand, winter is the season of least rainfall.

Mean annual temperatures range from 10°C in the south to 16°C in the north of New Zealand. The coldest month is usually July and the warmest month is usually January or February. In New Zealand

generally there are relatively small variations between summer and winter temperatures, although inland and to the east of the ranges the variation is greater (up to 14°C). Temperatures also drop about 0.7°C for every 100 m of altitude.

Sunshine hours are relatively high in areas that are sheltered from the west and most of New Zealand would have at least 2000 hours annually. The midday summer solar radiation index (UVI) is often very high in most places and can be extreme in northern New Zealand and in mountainous areas. Autumn and spring UVI values can be high in most areas.

Most snow in New Zealand falls in the mountain areas. Snow rarely falls in the coastal areas of the North Island and west of the South Island, although the east and south of the South Island may experience some snow in winter. Frosts can occur anywhere in New Zealand and usually form on cold nights with clear skies and little wind.

For this reason it is important to trial experimental clones across the range of climatic zones since clones have been found not to perform equally well in all regions of the country.

## **Methods**

The purpose of the trial was to compare field performance of experimental poplar material with already available commercial clones in a widely spaced agroforestry situation over a range of nationwide sites with contrasting climates (Table 1). The trial sites are located at Parakai, 50 km northwest of Auckland, Mapiu 30 km north of Taumaranui, Rissington 20 km northwest of Napier, Ashhurst 17 km northeast of Palmerston North, Windwhistle 50 km west of Christchurch and at Miller's Flat, 60 km southeast of Alexandra (Figure 1). Site information is given in Table 2.

Ten New Zealand bred clones were used in the trial each year of which four were experimental *P. maximowiczii* × *P. nigra* clones and the remaining six were commercially available clones. The clones of *P. maximowiczii* × *P. nigra* were selected for vigour, form, resistance to rust and possum grazing from a large number of seedlings. The four experimental clones were NZ93-005-002 (blue/red), NZ93-005-007 (blue/brown), NZ93-005-009 (blue/green) and NZ93-005-010 (blue/orange). The clones are referred to by their colour code in the rest of the report. Ten of each clone were planted at each site in 1999 and 2000 and either 10 (Ashhurst and Miller's Flat) or five of each clone in 2001. Trials were established at the sites in three successive years, 1999-2001, except for Ashhurst and Miller's Flat (only 2000-2001) In 2001 the clone 'Toa' (Red) was replaced by 'Kawa' (Black).

The planting material was 3 m poles normally planted to a depth of 0.8 m. Experimental design was completely randomised blocks with each clone being represented once in each block. Poles of each

clone were painted with a particular colour (Table 3). Poles were planted in rows at 10 m spacing within rows and 20 m between rows. The trial was marked out on the site and a planting plan supplied to the landowner who then planted the supplied colour-coded material. All material was sourced from the National Poplar and Willow Breeding nursery at Aokautere. Normally farmers would enclose the poles with plastic sleeves to prevent grazing stock eating the bark, and cattle are excluded from the paddock until the trees are at least three years old.

Table 1. Climatic data for climatic zones where the trial sites were located.

	Parakai	Mapiu	Rissington	Ashhurst	Windwhistle	Miller's Flat
Climate zone	Northern New Zealand	Central North Island	Eastern North Island	South-west North Island	Eastern South Island	Inland South Island
Mean max temperature	19.5	18.5	19.3	18.4	17.0	17.9
Mean min. temperature	11.9	7.7	9.5	8.8	7.0	4.7
Mean daily temperature	15.4	10.6	14.4	13.1	10.8	8.7
Mean max. temperature						
Summer	22-26	21-26	20-28	19-24	18-26	20-26
winter	12-17	10-14	10-16	10-16	7-14	3-11
sunshine hours/year	2000	2000	2200	1900	2000	2000
Prevailing wind	SW	SW	W	NW	NW (sum.) SW (wint.)	NW
Mean No. of frosts/yr	<1	32	7	16	36	83

At each trial site successive year's plantings were located conjointly, or close by in a similar situation.

The sites were visited and heights and survival measured in 2002, 2004 and 2007.

Height and diameter at breast height (DBH) was measured for the trees at the different sites between April 27 and July 18, 2007. Any deaths were recorded. Only 2007 data are reported here.

Table 2. Site information for each site (rainfall figures supplied by the landowners).

Trial site	Parakai	Mapiu	Rissington	Ashhurst	Windwhistle	Miller's Flat
Latitude	36° 39'	38° 38'	39° 26'	40° 17'	43° 31'	45° 45'
Longitude	174° 24'	175° 13'	176° 41'	175° 47'	171° 40'	169° 28'
Altitude	30 m	360 m	190 m	200 m	280 m	200 m
Aspect	NW	N	variable	variable	SW, NE	SE
Mean annual rainfall	1166 mm	1478 mm	1150 mm	1172 mm	1010 mm	900 mm
Slope	15-28	22-32°	5-22°	20-30°	0-19°	12-28°
Soil type	Sandy clay loam	clay	Sandy-loam	Clay-loam	Stony, some clay	Silt-loam
Previous use	grazing	grazing	grazing	grazing	grazing	grazing

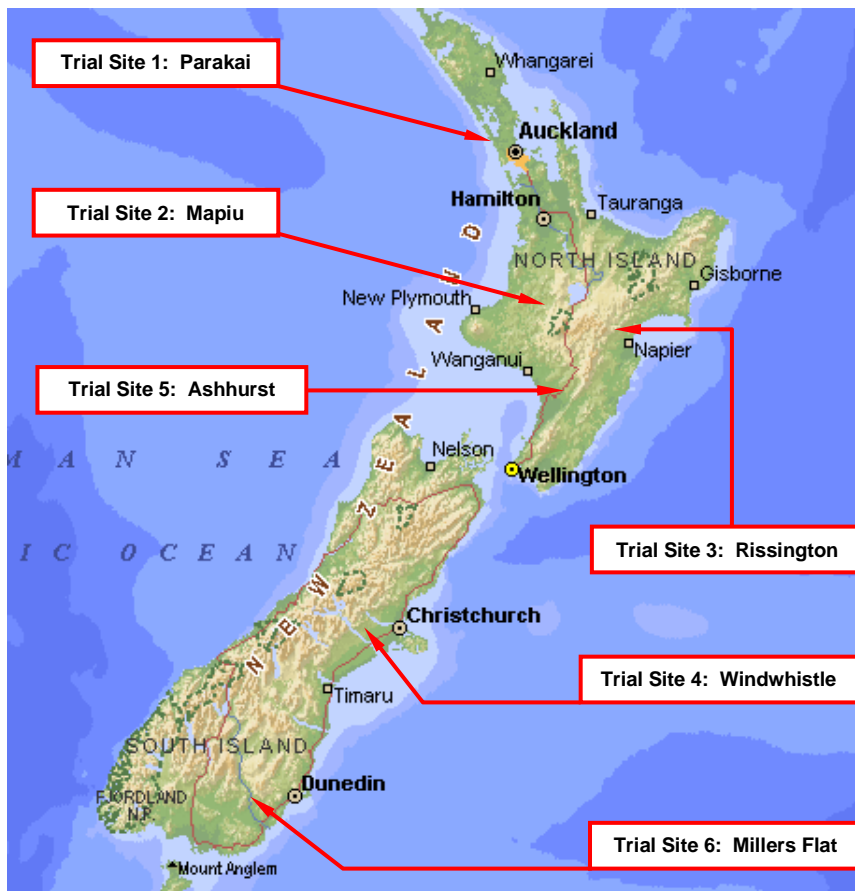


Figure 1. Location of the trial sites

Table 3. Trial clones with colour code used for field identification.

Clone	Colour Code	Clone	Colour Code
Shinsei	Blue	Selwyn	Green
Maxi-Nigra	Blue/Brown	Otahuaio	Grey
Maxi-Nigra	Blue/Green	Toa	Red
Maxi-Nigra	Blue/Orange	Dudley	White
Maxi-Nigra	Blue/Red	Kawa	Black
Weraiti	Brown		

### Statistics

One- and two-way ANOVA (GenStat 8<sup>th</sup> Edition) was used to analyse height from the three years of trials and DBH data from the 1999 trial for clone, site and clone-site differences. Because of the negligible survival rate, unrelated to the intrinsic properties of the trial trees, data from the 1999 Parakai trial and the 2000 and 2001 Windwhistle trials were not included in the statistical analyses

### Results

#### *General characteristics of the experimental clones*

All four clones were characterised by a dominant leader, straight stems, steeply angled and light branching, relatively smooth bark and a high degree of uniformity at similar locations. Double leaders were rare. Palatability of foliage to browsers, e.g. possums, was not able to be measured, neither was the degree to which bark might be damaged by browsing stock.

#### *Survival*

Survival for each of the clones is shown in Table 4. Mortality was high at some sites in some years, and this was attributed to a range of unfortunate reasons, including poor planting (Windwhistle in 2000 and 2001), stock damage (deer at Parakai in 1999, goats at Mapiu in 2001 and cattle at Windwhistle in 2001), severe cold frosts (Miller's Flat 2001) and unsuitability (dry, windy) of the site (Parakai 1999, part of Rissington 1999). Of particular note was that survival of the experimental clones was much higher at Miller's Flat during the cold winter of 2001 compared with most of the commercial clones. Data from the 1999 trial at Parakai, and the 2000 and 2001 trials at Windwhistle have been included in the survival table (Table 4) but because of the very low survival have been omitted from all subsequent performance analyses. While there is variability between sites attributable to the factors mentioned previously survivorship across all trials is very similar for both experimental and commercial clones.

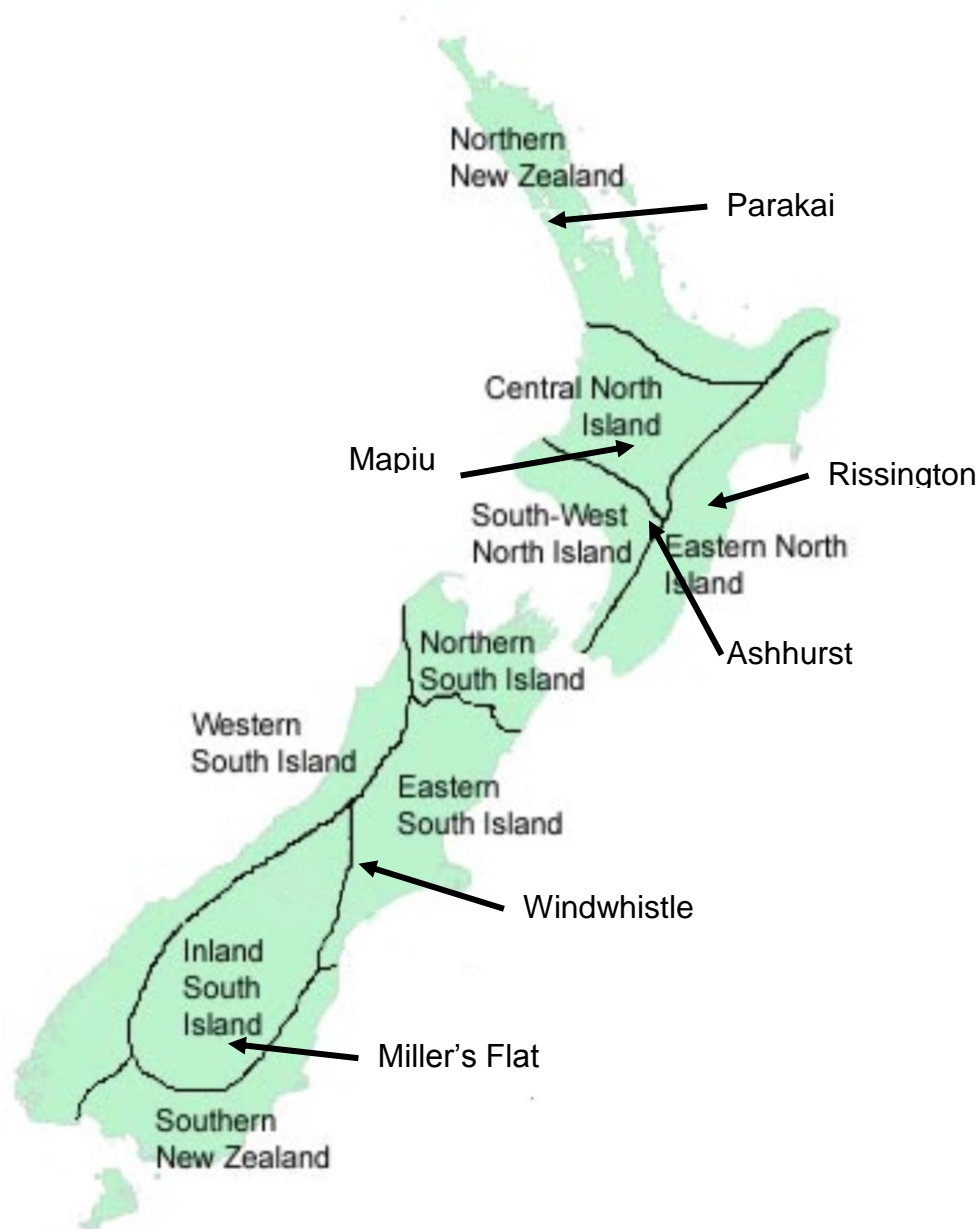


Figure 2. Location of the trial sites in the different climatic zones in New Zealand (map courtesy of NIWA, [www.niwascience.co.nz/edu/resources/climate/overview](http://www.niwascience.co.nz/edu/resources/climate/overview))

### *Performance*

#### a. Height

Of the four experimental clones with a common parentage showed different responses in the range of environments provided by this trial. Analysis of the data has been separated by years since the differences between years are still significant for poplar trees at these ages. The trials were planted over three successive years to ensure against planting failure in any one (or possibly two) year. As it turned out this is exactly what happened at two of the sites, Parakai in 1999 and Windwhistle in 2000

and 2001. Because of the low survival in Mapiu and at Miller's Flat in 2001 analyses of these data should also be viewed with caution.

The experimental clone labelled blue/green was the tallest clone at most trial sites in most years (Table 6, Figure 3). Of the other three experimental clones blue/orange and blue/brown performed above or among the best performed of the commercial clones in the 1999 trials where differences were likely to be greatest. Blue/red is in the middle of the clones in the 2001 trials but older trees (i.e. 2000, 1999 trial trees) have performed at the lower end of the clonal mixture. When compared with Shinsei (a currently available commercial maxi-nigra hybrid) the blue/green clone was significantly higher ( $p < 0.05$ ) in 1999 but the differences were not significant in 2000 and 2001.

Considering height data from all sites collectively the experimental maxi-nigra clones (in order blue/green, blue/brown, blue/orange and blue/red) ranked 1, 2, 5 and 10 in height in 1999, 1, 10, 6 and 8 in 2000, and 2, 6, 3 and 5 in 2001. The blue/green clone was significantly higher than all other clones ( $p < 0.05$ ) in the 1999 trials at Mapiu and Windwhistle but was exceeded by Weraiti at Rissington though the difference was not significant at  $p = 0.05$  (Table 8(a)). This trend was less apparent in the 2000 and 2001 trials

#### b. Diameter at breast height (DBH)

Mean DBH across all sites is presented in table 7. Values in 1999 were highest for Shinsei, blue/green, blue/brown and Toa. Differences were not significant between these four clones.

For several clones mean DBH for 2000 trial trees at Mapiu and Rissington was higher than for 1999 trial trees. This reflects the moister environment in which the 2000 trials were planted, so a comparison between years is not appropriate. Blue/green had the highest mean DBH of all tested clones in all years, excepting Kawa in 2001. though Kawa had a lower survival rate.

Of the other experimental clones blue/brown ranked 3, 7 and 8 for the three trial years, blue/orange 5, 6, 4 and blue/red 9, 10 and 10.

Clone, site and clone-site interactions are summarised in tables 8 and 9. Clone interactions are to be read in columns, site interactions across rows, and clone-site interactions across rows and down columns.

All experimental clones planted in the 1999 trials grew significantly better at Mapiu than at Rissington or Windwhistle (Table 8a). Comparing the performance of the experimental clones in the 2000 and 2001 trials, Mapiu and Rissington were more favourable sites than were Parakai, Ashhurst or Miller's Flat (Table 8e., 8h).

## **Discussion and conclusions**



The trials have been established in different climatic zones throughout New Zealand. These climatic zones vary in their mean daily temperature, their exposure to wind, their proneness to summer drought, their average rainfall and the severity of their winter and out of season frosts. While the average rainfall for the six trial sites did not vary greatly, Rissington and Windwhistle are prone to summer drought. Trees at Rissington planted high on the slope either did not survive or were very stunted at the time data was collected. Some trees survived for the first 2-4 years (data not shown) but subsequently died, probably due to insufficient soil moisture during the growing season when the tree is in full canopy. This tree response is to be expected for all poplar clones, particularly where trees are planted on a rise, hill or ridge, and where wind run is strong. The lower performance of the trees at Miller's Flat is accounted for by the lower mean daily temperatures in autumn and spring reducing the length of the growing season, and the frequency of late frosts in spring. This is a particularly good site to test cold tolerance of the experimental clones. Ashhurst site is very exposed to strong westerly winds and consequently trees are growing at lower mean temperatures over the growing season and were prone to water stress where planting coincided with a rise or ridge. At Mapiu the 1999 and 2000 trial sites are very well watered being towards the bottom of a high slope and protected from the prevailing wind. Survival of the experimental clones was comparable with the commercial clones included in the trials, except at Miller's Flat where the Maxi-nigra clones appeared to show greater tolerance to the very cold winter and spring conditions (data not shown) between measurements in 2004 and 2007. Survival was recorded at 82% in 2004 and at 47% in 2007.

Where there is such variability in trial conditions it is most appropriate to concentrate on comparative performance between clones at a single site. At Parakai experimental clones except for blue/red had a survival rate lower than the mean rate for the site. This site is quite close to the coast and maxi-nigra clones may be more susceptible to salt spray, though this was hard to evaluate. The experimental clones (together with Shinsei) were the poorest performers of the 2000 trial and were no better than commercial clones in the 2001 trial, except for blue/green.

At Mapiu where there are no obvious limiting factors on poplar growth at the locations of the 1999 and 2000 trials as indicated by both survival and growth of all clones, the experimental clones (blue/red excepted) had a higher survival rate (not significant) and outperformed all other commercial clones with the exception of Toa.

At Rissington where summer drought is the major limiting factor restricting where poplars are likely to survive and perform well, survival for the experimental clones was generally lower than the mean survival rate. Performance of the blue/green clone was significantly better than almost all other clones in all years, but of the remaining three experimental clones, none stood out as performing better than the commercial clones tested.

At Ashhurst, while cattle did contribute to tree mortality, the limiting factor to survival and growth is the prevailing wind. This site is exposed and a good site to test wind tolerance. Survival was lower in the experimental clones in the 2001 trial, but about the same in the 2000 trial. Certainly survival was

not higher. Blue/green was among the top performers. Two commercial clones grew taller but the differences were not significant ( $p>0.05$ ). Selwyn and Weraiti would appear to be better options in such sites.

At Windwhistle the limiting factors are drought and drying north-west winds in summer. This can be alleviated by irrigation of the trees during the establishment phase. The trial was not irrigated and the survival of the 1999 trial was aided by conifer shelterbelt protection. Performance of the experimental clones was only matched by Shinsei and Toa, blue/green performing significantly better than all other clones. Blue/brown performed well, though not significantly so. Blue/green performed better than Shinsei in both summer-dry environments (Rissington and Windwhistle) and equally well in summer-moist environment (Mapiu) and will add to the range of options after commercial release.

At Miller's Flat the limiting factor is prolonged severe cold, which may kill poplar trees during the establishment years (in this case between years 1-6 after planting). The experimental clones survived those years much better than the clones without a maxi-nigra phenotype, and performed either better or equally as well as the commercial clones, certainly as well as Shinsei. Blue/red performed relatively better in this environment than in the other trial sites.

Overall ranking based on height and DBH including data where there is a single point only (Table 10) shows that compared with the commercial clones tested in the trials blue/green was a top performing clone, blue/brown and blue/orange were average performing clones with above average performance in some sites, and blue/red was a poor performing clone.

## Conclusion

Of the four experimental clones trialled, blue/green should be released for commercial use across all climatic zones in New Zealand, blue/brown could be considered for release for use in climatic zones with regular summer rain or on lower slopes where water stress will be lower, blue/orange should be released for use across all climatic zones, and blue/red could be considered for further trials in particular local environments or for use where lower vigour would be an advantage.

Table 4. Numbers of each clone planted in trial years 1999-2001 and surviving in 2007 at each site.

Clone	Number surviving at each trial site						Total	%survival
	1999	Parakai	Mapiu	Rissing- ton	W'wistle	Ashhurst		
Shinsei	1	9	7	10			27	68
Blue/Brown	0	8		10			18	45
Blue/Green	0	9	6	10			25	63
Blue/Orange	0	9	5	10			24	60
Blue/Red	0	10	6	10			26	65
Weraiti	1	9	6	9			25	63
Selwyn	0	7	9	9			25	63
Otahuaao	0	8	5	10			23	58
Toa	1	8	5	10			24	60
Dudley	1	8	6	9			24	60
	4	85	55	97			241	
2000	Parakai	Mapiu	Rissington	W'wistle	Ashhurst	Millers Flat		2000
Shinsei	3	10	8	0	9	7	37	62
Blue/Brown	9	10	5	0	7	6	37	62
Blue/Green	4	10	9	1	6	8	38	63
Blue/Orange	7	9	8	1	6	10	41	68
Blue/Red	8	10	6	0	8	9	41	68
Weraiti	10	9	9	0	7	6	41	68
Selwyn	8	9	10	1	8	7	43	72
Otahuaao	8	9	8	0	9	9	43	72
Toa	6	8	9	1	8	8	40	67
Dudley	7	8	10	0	9	9	43	72
	70	92	82	4	77	79	404	
2001	Parakai	Mapiu	Rissington	W'wistle	Ashhurst	Millers Flat		2001
Shinsei	4	3	4	0	5	7	23	58
Blue/Brown	1	5	1	0	8	7	22	55
Blue/Green	3	2	4	0	1	10	20	50
Blue/Orange	1	3	5	0	6	8	23	58
Blue/Red	3	1	5	0	1	10	20	50
Weraiti	3	4	5	0	10	0	22	55
Selwyn	3	1	5	0	6	1	16	40
Otahuaao	5	0	5	0	5	1	16	40
Kawa	4	5	1	0	6	0	16	40
Dudley	4	2	5	0	9	3	23	58
	31	26	40	0	57	47	201	

Table 5 Survival % of each clone at each site for all trial years, with % survival in each year

<b>Clone</b>	<b>Parakai</b>	<b>Mapiu</b>	<b>Rissington</b>	<b>Ashhurst</b>	<b>Wind-whistle</b>	<b>Millar's Flat</b>	<b>All sites %</b>
Shinsei	47	88	76	70	100	70	75
Blue/Brown	67	92	40	75	100	65	73
Blue/Green	47	84	76	35	100	90	71
Blue/Orange	53	84	76	60	100	90	76
Blue/Red	73	84	68	45	100	95	74
Weraiti	87	88	80	85	90	30	76
Selwyn	73	68	96	70	90	40	72
Otahuaao	87	68	72	70	100	50	71
Toa	60	80	70	80	100	80	78
Dudley	73	72	84	90	90	60	77
Kawa	80	100	20	60	NA	0	57
<b>Total</b>							
%	67	79	81	67	97	63	
% 1999	#	85	61	NA	97	NA	82
% 2000	70	92	82	77	#	79	80
% 2001	62	52	80	57	#	47	57

NA = no trial, # = discounted (see table 4)

Table 6 Mean heights ( $\pm$  = S.E.) of clones at each site and across all sites as measured between April 27 and July 18, 2007. Heights are in metres.

Year	Clone	Parakai	Mapiu	Rissing-ton	Ashhurst	Wind-whistle	Miller's Flat	All sites
1999	Shinsei	11.5*	11.2 $\pm$ 3.3	9.6 $\pm$ 3.1	#	9.6 $\pm$ 2.1	#	10.18 $\pm$ 2.81
1999	Blue/Brown	**	11.6 $\pm$ 2.9	#	#	9.4 $\pm$ 1.9	#	10.40 $\pm$ 2.81
1999	Blue/Green	**	13.4 $\pm$ 3.1	10.7 $\pm$ 2.6	#	11.2 $\pm$ 1.2	#	11.91 $\pm$ 2.58
1999	Blue/Orange	**	11.8 $\pm$ 2.9	7.9 $\pm$ 3.5	#	9.1 $\pm$ 1.3	#	9.85 $\pm$ 2.81
1999	Blue/Red	**	9.2 $\pm$ 3.0	9.5 $\pm$ 2.1	#	9.0 $\pm$ 1.8	#	8.49 $\pm$ 2.56
1999	Weraiti	16.7*	9.7 $\pm$ 3.1	9.9 $\pm$ 2.2	#	8.5 $\pm$ 1.5	#	10.09 $\pm$ 2.85
1999	Selwyn	**	8.4 $\pm$ 1.5	10.1 $\pm$ 2.5	#	8.4 $\pm$ 1.6	#	8.57 $\pm$ 1.88
1999	Otahuaao	**	8.7 $\pm$ 2.2	9.6 $\pm$ 3.8	#	8.4 $\pm$ 1.8	#	8.69 $\pm$ 2.39
1999	Toa	9.9*	11.2 $\pm$ 3.3	9.6 $\pm$ 3.1	#	9.7 $\pm$ 0.8	#	10.18 $\pm$ 2.39
1999	Dudley	16.1*	9.5 $\pm$ 2.4	8.9 $\pm$ 3.8	#	8.7 $\pm$ 2.1	#	9.42 $\pm$ 2.88
2000	Shinsei	5.4 $\pm$ 0.7	10.9 $\pm$ 1.0	8.7 $\pm$ 2.6	6.8 $\pm$ 2.0	**	7.2 $\pm$ 1.9	8.27 $\pm$ 2.48
2000	Blue/Brown	5.5 $\pm$ 1.4	10.4 $\pm$ 2.5	7.6 $\pm$ 0.9	5.6 $\pm$ 1.4	**	7.0 $\pm$ 2.0	7.26 $\pm$ 2.57
2000	Blue/Green	6.0*	12.9 $\pm$ 1.8	12.8 $\pm$ 2.4	7.0 $\pm$ 1.6	**	6.9 $\pm$ 3.5	10.00 $\pm$ 3.54
2000	Blue/Orange	5.0 $\pm$ 1.8	11.5 $\pm$ 2.8	8.5 $\pm$ 2.5	6.6 $\pm$ 1.9	**	6.7 $\pm$ 2.3	7.86 $\pm$ 3.02
2000	Blue/Red	4.4 $\pm$ 0.8	11.1 $\pm$ 3.2	9.1 $\pm$ 2.9	5.8 $\pm$ 1.8	**	6.6 $\pm$ 2.4	7.38 $\pm$ 3.29
2000	Weraiti	6.7 $\pm$ 2.4	9.1 $\pm$ 1.2	12.1 $\pm$ 4.0	7.8 $\pm$ 2.3	**	6.6 $\pm$ 2.1	8.63 $\pm$ 3.14
2000	Selwyn	5.8 $\pm$ 1.6	8.2 $\pm$ 1.7	10.2 $\pm$ 2.3	7.3 $\pm$ 1.8	**	6.5 $\pm$ 2.3	7.85 $\pm$ 2.27
2000	Otahuaao	6.9 $\pm$ 1.8	8.8 $\pm$ 2.4	8.9 $\pm$ 1.8	5.9 $\pm$ 1.5	**	6.4 $\pm$ 3.4	7.34 $\pm$ 2.16
2000	Toa	7.5 $\pm$ 2.0	11.5 $\pm$ 1.9	10.8 $\pm$ 2.8	6.3 $\pm$ 1.8	**	6.4 $\pm$ 3.1	8.99 $\pm$ 2.86
2000	Dudley	7.4 $\pm$ 3.0	8.7 $\pm$ 1.8	10.3 $\pm$ 1.9	6.5 $\pm$ 2.1	**	6.4 $\pm$ 3.1	8.11 $\pm$ 2.40
2001	Shinsei	4.6 $\pm$ 0.6	7.8 $\pm$ 1.9	6.4 $\pm$ 1.3	5.3 $\pm$ 0.6	**	5.2 $\pm$ 2.3	5.74 $\pm$ 1.50
2001	Blue/Brown	4.3*	6.8 $\pm$ 2.5	4.3*	5.8 $\pm$ 1.3	**	4.6 $\pm$ 2.6	5.53 $\pm$ 1.62
2001	Blue/Green	6.1 $\pm$ 1.9	9.6 $\pm$ 1.0	8.1 $\pm$ 1.1	4.6*	**	5.9 $\pm$ 4.0	6.43 $\pm$ 1.91
2001	Blue/Orange	8.1*	6.5 $\pm$ 0.5	6.6 $\pm$ 0.9	4.9 $\pm$ 0.7	**	4.7 $\pm$ 2.0	6.10 $\pm$ 1.97
2001	Blue/Red	4.5 $\pm$ 0.2	6.3 $\pm$ 1.3	5.7 $\pm$ 0.8	5.4*	**	5.7 $\pm$ 1.8	5.56 $\pm$ 1.00
2001	Weraiti	5.2 $\pm$ 0.7	5.9*	6.7 $\pm$ 0.9	4.6 $\pm$ 0.5	**	**	5.48 $\pm$ 1.20
2001	Selwyn	4.5 $\pm$ 0.8	**	5.9 $\pm$ 2.0	5.4 $\pm$ 1.3	**	5.7*	5.44 $\pm$ 1.39
2001	Otahuaao	5.6 $\pm$ 1.4	6.8 $\pm$ 0.7	5.2 $\pm$ 1.0	5.2 $\pm$ 0.5	**	6.5*	5.39 $\pm$ 0.97
2001	Kawa	9.3 $\pm$ 2.4	8.5 $\pm$ 1.8	7.9 $\pm$ 1.1	5.1 $\pm$ 1.5	*&*	* *	6.77 $\pm$ 2.66
2001	Dudley	4.8 $\pm$ 0.6	6.5*	6.1 $\pm$ 0.6	5.3 $\pm$ 1.7	**	5.3 $\pm$ 2.6	5.52 $\pm$ 1.00

# no trial      \*\* nil survival    \* single survivor only

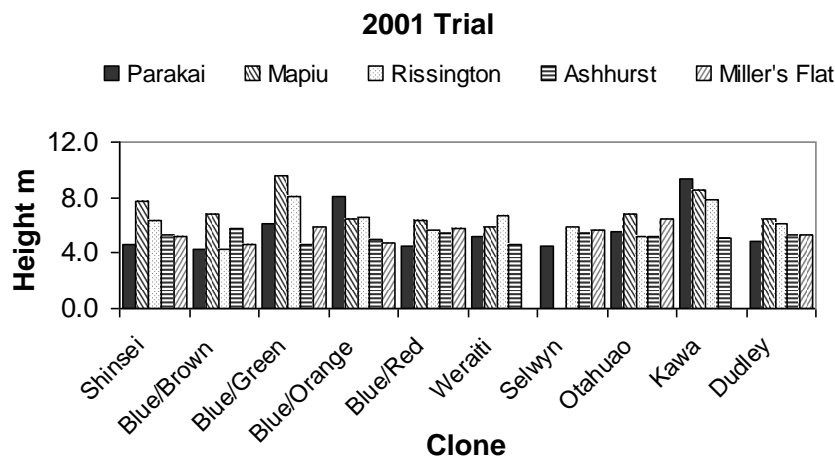
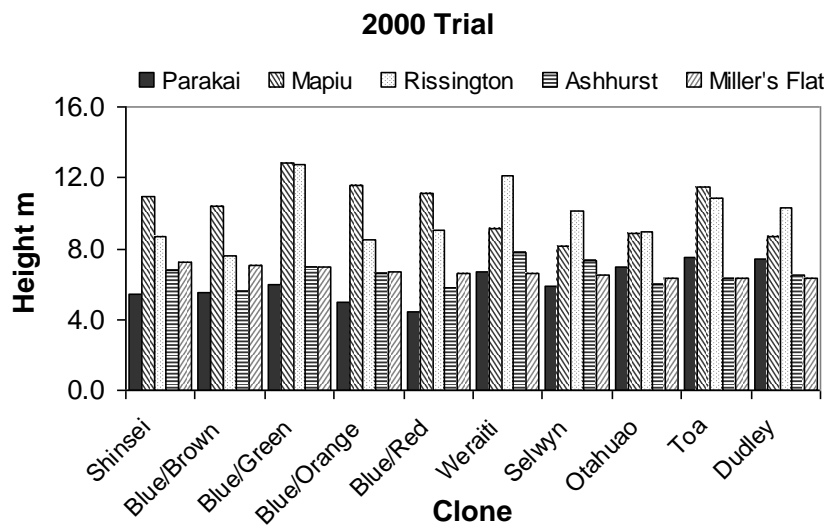
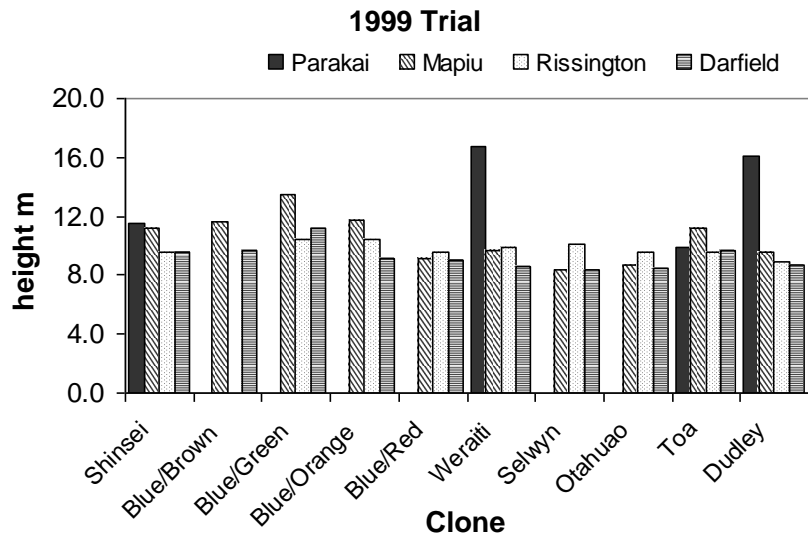


Figure 3. Heights of the different clones compared between the trial sites.

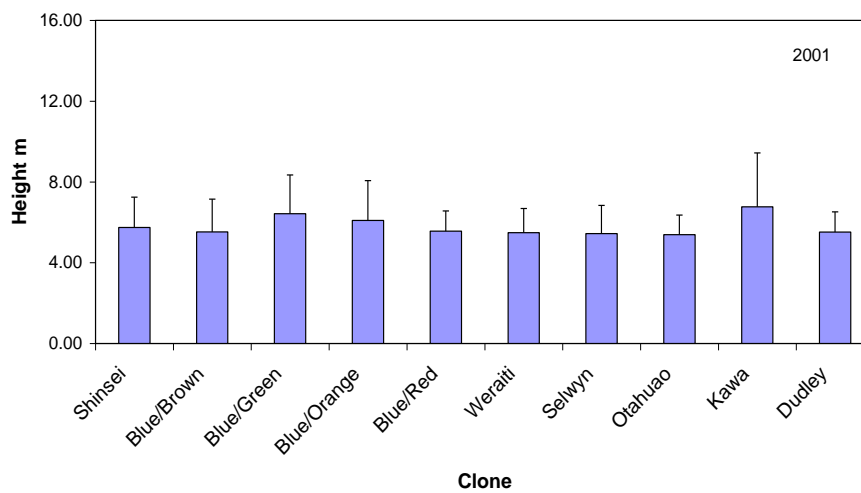
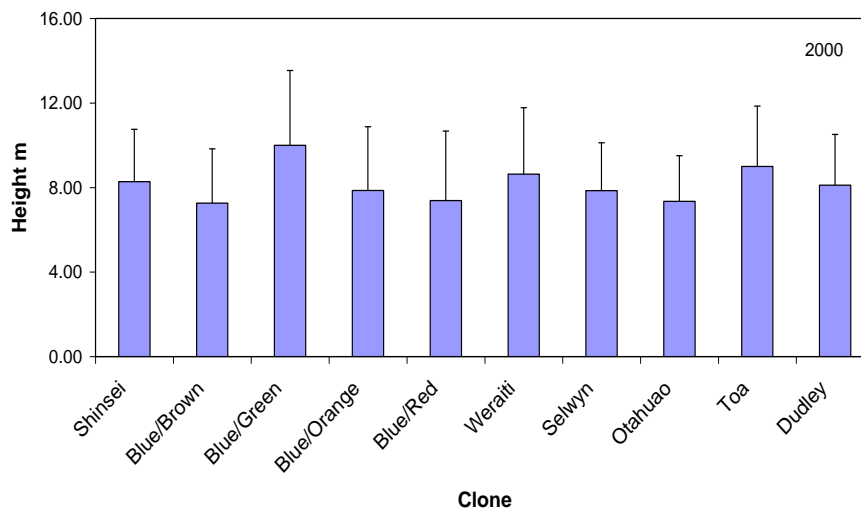
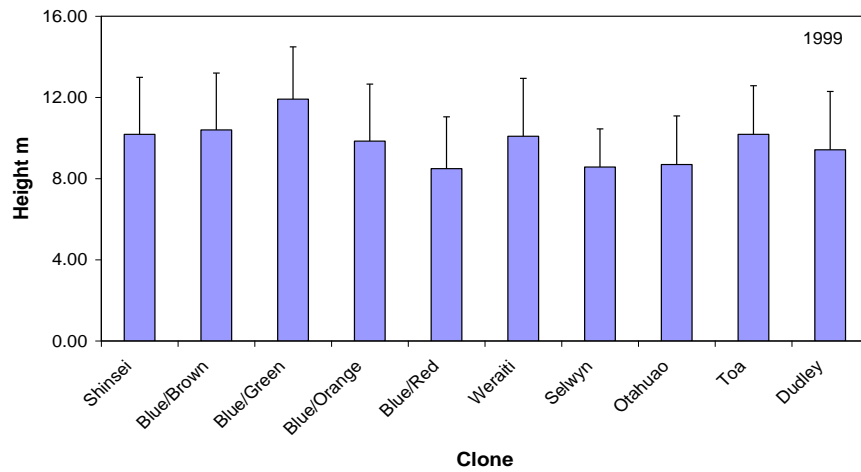


Figure 4. Mean heights of the different clones in each trial year including all trial sites. Bars are standard error.

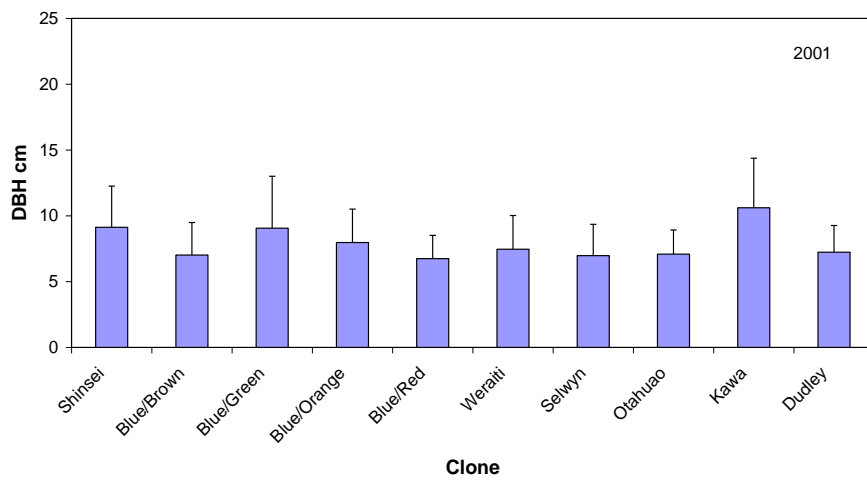
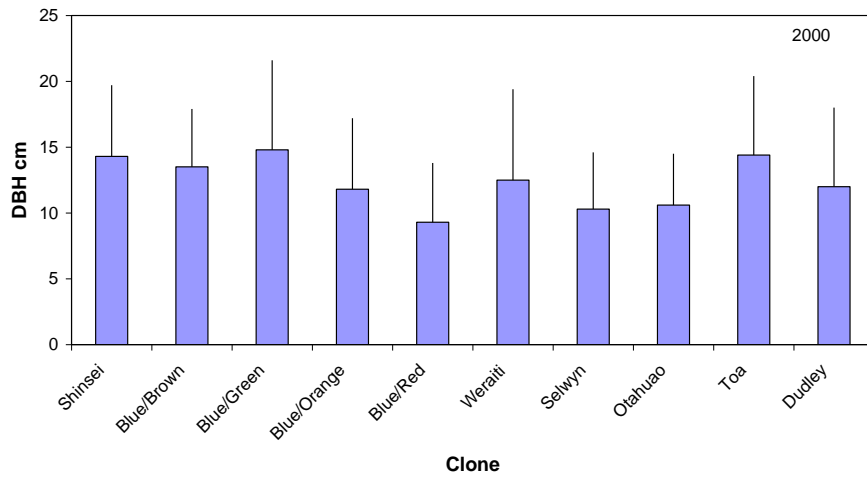
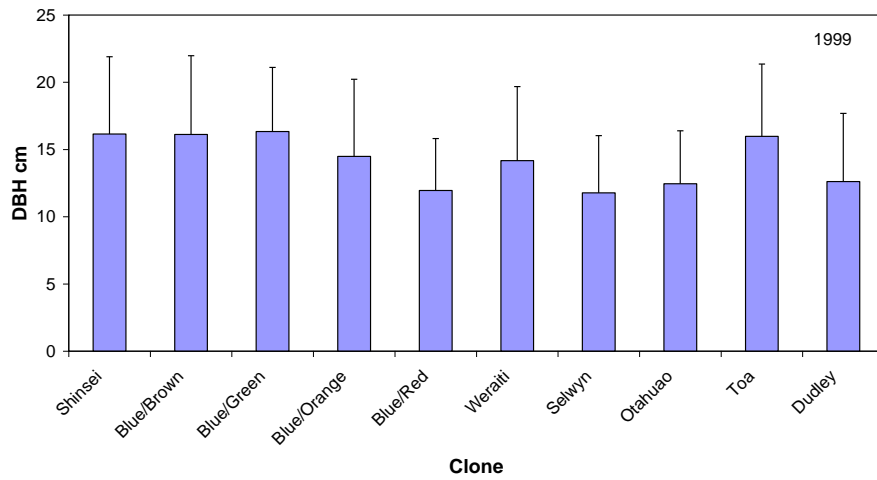


Figure 5. Diameters at breast height of the different clones in each trial year including all trial sites. Bars are standard error.



Table 7. Mean diameter at breast height (DBH) for each clone at each site in each year together with mean DBH across all sites ( $\pm$  = S.E.) \*\* = no trees, \* = single tree

1999		Site				
Clone	Parakai	Mapiu	Rissington	W'wistle		All sites
Shinsei	*16.3	18.0 $\pm$ 6.2	16.6 $\pm$ 6.4	14.2 $\pm$ 5.0		16.2 $\pm$ 5.7
Blue/Brown	**	17.5 $\pm$ 6.3	**	14.9 $\pm$ 2.7		16.1 $\pm$ 4.8
Blue/Green	**	18.3 $\pm$ 7.4	15.6 $\pm$ 4.6	14.9 $\pm$ 2.2		16.3 $\pm$ 5.3
Blue/Orange	**	18.1 $\pm$ 5.3	11.4 $\pm$ 4.5	12.8 $\pm$ 1.8		14.5 $\pm$ 4.8
Blue/Red	**	11.9 $\pm$ 5.2	10.4 $\pm$ 2.4	12.9 $\pm$ 2.9		11.9 $\pm$ 3.9
Weraiti	*25	12.0 $\pm$ 5.0	17.6 $\pm$ 3.8	12.0 $\pm$ 4.8		14.2 $\pm$ 5.5
Selwyn	**	9.5 $\pm$ 0.7	14.1 $\pm$ 5.4	11.2 $\pm$ 3.7		11.8 $\pm$ 4.3
Otahuaao	**	10.4 $\pm$ 2.3	15.6 $\pm$ 6.0	12.6 $\pm$ 2.9		12.5 $\pm$ 4.0
Toa	*16.5	17.4 $\pm$ 7.3	14.8 $\pm$ 6.7	15.3 $\pm$ 2.9		16.0 $\pm$ 5.4
Dudley	*25.7	10.6 $\pm$ 1.9	13.7 $\pm$ 6.5	12.2 $\pm$ 4.2		12.6 $\pm$ 5.1
	20.9 $\pm$ 5.2	14.5 $\pm$ 6.2	14.5 $\pm$ 5.4	13.3 $\pm$ 3.5		
<b>2000</b>						
Clone	Parakai	Mapiu	Rissington	Ashhurst	Millers Flat	All sites
Shinsei	7.1 $\pm$ 2.3	18.4 $\pm$ 3.8	13.6 $\pm$ 6.1	12.1 $\pm$ 5.6	15.1 $\pm$ 1.9	14.3 $\pm$ 5.4
Blue/Brown	8.1 $\pm$ 2.5	15.2 $\pm$ 4.1	13.5 $\pm$ 4.5	8.0 $\pm$ 2.8	10.0 $\pm$ 2.0	11.0 $\pm$ 4.4
Blue/Green	8.4 $\pm$ 3.4	20.1 $\pm$ 3.4	18.6 $\pm$ 7.8	8.6 $\pm$ 2.4	11.4 $\pm$ 3.5	14.8 $\pm$ 6.8
Blue/Orange	6.9 $\pm$ 3.3	17.2 $\pm$ 4.3	12.9 $\pm$ 6.6	8.9 $\pm$ 3.2	10.9 $\pm$ 2.3	11.8 $\pm$ 5.4
Blue/Red	5.1 $\pm$ 0.9	13.5 $\pm$ 3.9	11.6 $\pm$ 6.0	7.0 $\pm$ 2.4	8.7 $\pm$ 2.4	9.3 $\pm$ 4.5
Weraiti	8.6 $\pm$ 4.5	10.0 $\pm$ 2.8	21.9 $\pm$ 7.5	9.3 $\pm$ 4.4	12.6 $\pm$ 2.1	12.5 $\pm$ 7.0
Selwyn	6.8 $\pm$ 2.0	7.8 $\pm$ 1.5	15.6 $\pm$ 4.3	*8.9	11.8 $\pm$ 2.3	10.3 $\pm$ 4.3
Otahuaao	9.7 $\pm$ 3.6	11.0 $\pm$ 3.4	15.2 $\pm$ 3.0	*7.4	10.4 $\pm$ 3.4	10.6 $\pm$ 3.9
Toa	10.3 $\pm$ 2.8	16.9 $\pm$ 2.8	20.2 $\pm$ 6.1	8.0 $\pm$ 2.2	15.1 $\pm$ 4.8	14.4 $\pm$ 6.0
Dudley	11.0 $\pm$ 7.7	9.0 $\pm$ 1.7	19.2 $\pm$ 4.7	7.8 $\pm$ 3.5	11.8 $\pm$ 3.1	12.0 $\pm$ 6.0
	8.2 $\pm$ 3.9	14.0 $\pm$ 5.2	16.5 $\pm$ 6.5	8.6 $\pm$ 3.4	11.7 $\pm$ 3.4	
<b>2001</b>						
Clone	Parakai	Mapiu	Rissington	Ashhurst	Millers Flat	All sites
Shinsei	5.1 $\pm$ 0.6	*11.2	11.6 $\pm$ 3.0	9.7 $\pm$ 2.9	8.4 $\pm$ 2.3	9.1 $\pm$ 3.1
Blue/Brown	*6.2	8.2 $\pm$ 4.3	*7.6	*4.8	7.0 $\pm$ 2.6	7.0 $\pm$ 2.5
Blue/Green	8.7 $\pm$ 3.1	12.5 $\pm$ 2.9	12.2 $\pm$ 2.9	6.6 $\pm$ 0.9	8.1 $\pm$ 4.7	9.1 $\pm$ 3.9
Blue/Orange	*11.1	7.2 $\pm$ 1.1	10.2 $\pm$ 2.1	*7.4	6.5 $\pm$ 2.0	8.0 $\pm$ 2.5
Blue/Red	4.8 $\pm$ 0.6	7.4 $\pm$ 1.5	7.6 $\pm$ 1.4	5.5 $\pm$ 0.9	7.9 $\pm$ 1.8	6.7 $\pm$ 1.8
Weraiti	5.3 $\pm$ 0.8	*5.0	9.9 $\pm$ 1.9	7.0 $\pm$ 2.35	**	7.5 $\pm$ 2.6
Selwyn	4.5 $\pm$ 0.3	**	8.7 $\pm$ 3.0	6.5 $\pm$ 0.8	*8.2	7.0 $\pm$ 2.4
Otahuaao	6.4 $\pm$ 1.9	7.8 $\pm$ 1.6	7.9 $\pm$ 2.0	6.3 $\pm$ 1.3	*9.8	7.1 $\pm$ 1.8
Kawa	13.3 $\pm$ 3.8	11.0 $\pm$ 4.8	12.30 $\pm$ 2.1	7.2 $\pm$ 1.0	**	10.6 $\pm$ 3.8
Dudley	5.6 $\pm$ 1.1	*4.9	8.7 $\pm$ 1.4	6.6 $\pm$ 1.1	9.8 $\pm$ 2.6	7.2 $\pm$ 2.0
	6.9 $\pm$ 3.3	9.2 $\pm$ 3.4	9.6 $\pm$ 2.6	6.9 $\pm$ 2.0	7.8 $\pm$ 2.9	7.9 $\pm$ 2.9

Table 8. Analyses of height data using two-way ANOVA (GenStat 8<sup>th</sup> Ed.). Means followed by the same letters indicate no significant difference at 5%

(a) **1999 height** Clone interaction, i.e. all clones compared within a single site l.s.d. at 5% = 1.250

Clone	Mapiu	Rissington	Windwhistle	All sites
Shinsei	11.2±3.3b	9.6±3.1b	9.6±2.1bc	10.2±2.8b
Blue/Brown	11.6±2.9b		9.4±1.8bc	10.4±2.6b
Blue/Green	13.4±3.1a	10.7±2.6ab	11.2±1.2a	11.9±2.6a
Blue/Orange	11.8±2.9b	7.9±3.5cd	9.1±1.3bc	9.8±2.9bc
Blue/Red	9.2±3.0c	6.5±2.1d	9.0±1.8bc	8.5±2.6c
Weraiti	9.7±3.1c	11.3±2.2a	8.6±1.5bc	10.1±2.9b
Selwyn	8.4±1.5c	8.9±2.5c	8.4±1.6c	8.6±1.9c
Otahuao	8.7±2.2c	9.6±3.8bc	8.4±1.8c	8.8±2.4c
Toa	11.2±3.3b	9.6±3.1bc	9.7±0.8b	10.2±2.4b
Dudley	9.5±2.4c	8.9±3.8c	8.8±2.1bc	9.4±2.9bc

(b) **1999 height** Site interaction, i.e. single clone compared between sites l.s.d. at 5% = 0.685

Clone	Mapiu	Rissington	Windwhistle	
Shinsei	11.2±3.3a	9.6±3.1b	9.6±2.1b	
Blue/Brown	11.6±2.9a		9.4±1.8b	
Blue/Green	13.4±3.1a	10.7±2.6b	11.2±1.2b	
Blue/Orange	11.8±2.9a	7.9±3.5c	9.1±1.3b	
Blue/Red	9.2±3.0a	6.5±2.1b	9.0±1.8a	
Weraiti	9.7±3.1b	11.3±2.2a	8.6±1.5c	
Selwyn	8.4±1.5a	8.9±2.5a	8.4±1.6a	
Otahuao	8.7±2.2b	9.6±3.8a	8.4±1.8b	
Toa	11.2±3.3a	9.6±3.1b	9.7±0.8b	
Dudley	9.5±2.4a	8.9±3.8ab	8.8±2.1b	
	10.5±3.1	9.3±3.1	9.2±1.8	

(c) **1999 height** Site x clone interaction, i.e. all clones compared across all sites l.s.d. at 5% = 2.166

Clone	Mapiu	Rissington	Windwhistle	
Shinsei	11.2±3.3b	9.6±3.1b	9.6±2.1b	
Blue/Brown	11.6±2.9ab		9.4±1.8bc	
Blue/Green	13.4±1.3a	10.7±2.6b	11.2±1.2b	
Blue/Orange	11.8±2.9ab	7.9±3.5c	9.1±1.3c	
Blue/Red	9.2±3.0c	6.5±2.1d	9.0±1.8c	
Weraiti	9.7±3.1bc	11.3±2.2ab	8.6±1.5cd	
Selwyn	8.4±1.5cd	8.9±2.5c	8.4±1.6cd	
Otahuao	8.7±2.2cd	9.6±3.8c	8.4±1.8cd	
Toa	11.2±3.3b	9.6±3.1c	9.7±0.8b	
Dudley	9.5±2.4c	8.9±3.8c	8.8±2.1cd	

(d) **2000 height** Clone interaction, i.e. all clones compared within a single site l.s.d. at 5% = 0.7908

Clone	Parakai	Mapiu	Rissington	Ashhurst	Millers Flat
Shinsei	5.150cd	10.949b	8.712c	6.778b	7.229b
Blue/Brown	5.518c	10.381c	7.600d	5.571c	6.357c
Blue/Green	5.974bc	12.851a	12.789a	6.983a	7.563ab
Blue/Orange	5.003	11.534b	8.512c	6.633bc	6.760bc
Blue/Red	4.385d	11.105b	9.067c	5.763c	6.222c
Weraiti	6.714b	9.113d	12.122a	7.750a	6.917bc
Selwyn	5.836c	8.161e	10.160b	7.318a	7.057bc
Otahuao	6.946ab	8.842d	8.912c	5.944c	6.200c
Toa	7.517a	11.472b	10.844b	6.338bc	8.200a
Dudley	7.414ab	8.676de	10.340b	6.496bc	7.289b

(e). **2000 height** Site interaction, i.e. single clone compared between sites, l.s.d. at 5% = 0.5592

Clone	Parakai	Mapiu	Rissington	Ashhurst	Millers Flat
Shinsei	5.150d	10.949a	8.712b	6.778c	7.229c
Blue/Brown	5.518d	10.381a	7.600b	5.571d	6.357b
Blue/Green	5.974c	12.851a	12.789a	6.983b	7.563b
Blue/Orange	5.003d	11.534a	8.512b	6.633c	6.760c
Blue/Red	4.385e	11.105a	9.067b	5.763d	6.222c
Weraiti	6.714d	9.113b	12.122a	7.750c	6.917d
Selwyn	5.836d	8.161b	10.160a	7.318c	7.057c
Otahuao	6.946b	8.842a	8.912a	5.944d	6.200d
Toa	7.517d	11.472a	10.844b	6.338e	8.200c
Dudley	7.414c	8.676b	10.340a	6.496d	7.289c

(f) **2000 height**. Clone x site interaction, i.e. all clones compared across all sites l.s.d. at 5% = 1.7684

Clone	Parakai	Mapiu	Rissington	Ashhurst	Millers Flat
Shinsei	5.150def	10.949bc	8.712bcd	6.778cde	7.229cde
Blue/Brown	5.518def	10.381bc	7.600cd	5.571de	6.357cde
Blue/Green	5.974cde	12.851a	12.789a	6.983cde	7.563cd
Blue/Orange	5.003def	11.534ab	8.512bcd	6.633cde	6.760cde
Blue/Red	4.385ef	11.105ab	9.067bcd	5.763ef	6.222cde
Weraiti	6.714cde	9.113bcd	12.122ab	7.750bcd	6.917cde
Selwyn	5.836de	8.161bcd	10.160bc	7.318cde	7.057cde
Otahuao	6.946cdc	8.842bcd	8.912bcd	5.944cde	6.200cde
Toa	7.517cd	11.472ab	10.844bc	6.338cde	8.200bcd
Dudley	7.414cde	8.676bcd	10.340bc	6.496cde	7.289cde

(g) **2001 height** Clone interaction, i.e. all clones compared within a single site l.s.d. at 5% = 0.5540

Clone	Parakai	Mapiu	Rissington	Ashhurst	Millers Flat
Shinsei	4.570fg	8.493a	6.350cd	5.280ab	5.214bcd
Blue/Brown	4.253g	7.750b	4.302fg	5.812a	4.600cd
Blue/Green	6.080de	6.825cde	8.100a	4.657cd	5.922ab
Blue/Orange	8.126a	8.858a	6.600bc	4.917bc	4.687cd
Blue/Red	4.457fg	6.848cde	5.680def	5.416ab	5.720bc
Weraiti	5.170ef	6.337def	6.740bcd	4.610cd	5.108bcd
Selwyn	4.523fg	5.900efg	5.860cd	5.433ab	5.700bc
Otahuao	5.556de	7.503bcd	5.180efg	5.220bc	6.459a
Dudley	4.810efg	6.760cde	6.140cd	5.278ab	5.333bc

(h) **2001 height** Site interaction, i.e. single clone compared between sites l.s.d. at 5% = 0.4224

Clone	Parakai	Mapiu	Rissington	Ashhurst	Millers Flat
Shinsei	4.570d	8.493a	6.350b	5.280c	5.214c
Blue/Brown	4.253c	7.750a	4.302c	5.812b	4.600c
Blue/Green	6.080c	6.825b	8.100a	4.657d	5.922c
Blue/Orange	8.126b	8.858a	6.600c	4.917d	4.687d
Blue/Red	4.457c	6.848a	5.680b	5.416b	5.720b
Weraiti	5.170b	6.337a	6.740a	4.610c	5.108b
Selwyn	4.523c	5.900a	5.860ab	5.433b	5.700a
Otahuao	5.556c	7.503a	5.180c	5.220c	6.459b
Dudley	4.810cd	6.760a	6.140b	5.278cd	5.333c

(i) **2001 height** Clone x site interaction, i.e. all clones compared across all sites l.s.d. at 5% = 1.523

Clone	Parakai	Mapiu	Rissington	Ashhurst	Millers Flat
Shinsei	4.570bcd	8.493ab	6.350bc	5.280bcd	5.214bcd
Blue/Brown	4.253cd	7.750ab	4.302bcd	5.812bcd	4.600bcd
Blue/Green	6.080abc	6.825abc	8.100ab	4.657bcd	5.922abc
Blue/Orange	8.126ab	8.858a	6.600abc	4.917bcd	4.687bcd
Blue/Red	4.457bcd	6.848abc	5.680bc	5.416bcd	5.720bcd
Weraiti	5.170bcd	6.337bc	6.740abc	4.610bcd	5.108bcd
Selwyn	4.523bcd	5.900bc	5.860abc	5.433bcd	5.700bcd
Otahuao	5.556bcd	7.503ab	5.180bcd	5.220bcd	6.459abc
Dudley	4.810bcd	6.760abc	6.140abc	5.278bcd	5.333bcd

Table 9 Analyses of 1999 DBH data using two-way ANOVA (GenStat 8<sup>th</sup> Ed.). Means followed by the same letters indicate no significant difference at 5%

(a) 1999 DBH Clone interactions, l.s.d = 2.371

Clone	Mapiu	Rissington	Windwhistle
Shinsei	14.15ab	17.99ab	16.64ab
Blue/Brown	14.92ab		17.07ab
Blue/Green	14.86ab	18.26a	15.60ab
Blue/Orange	12.79ab	18.08a	11.42bcd
Blue/Red	12.91ab	11.92bcd	10.41cd
Weraiti	12.03ab	11.99bcd	17.56a
Selwyn	11.20ab	9.49cd	14.14abc
Otahuao	12.55ab	10.38cd	15.57ab
Toa	15.34a	17.44ab	14.83abc
Dudley	12.19ab	10.60cd	13.73abc

(b) 1999 DBH Site interactions, l.s.d = 1.299

Clone	Mapiu	Rissington	Windwhistle
Shinsei	14.15c	17.99a	16.64b
Blue/Brown	14.92b		17.07a
Blue/Green	14.86b	18.26a	15.60b
Blue/Orange	12.79b	18.08a	11.42b
Blue/Red	12.91a	11.92ab	10.41b
Weraiti	12.03b	11.99b	17.56a
Selwyn	11.20b	9.49c	14.14a
Otahuao	12.55b	10.38c	15.57a
Toa	15.34b	17.44a	14.83c
Dudley	12.19b	10.60c	13.73a

(c) 1999 DBH Clone x site interactions, l.s.d = 4.107

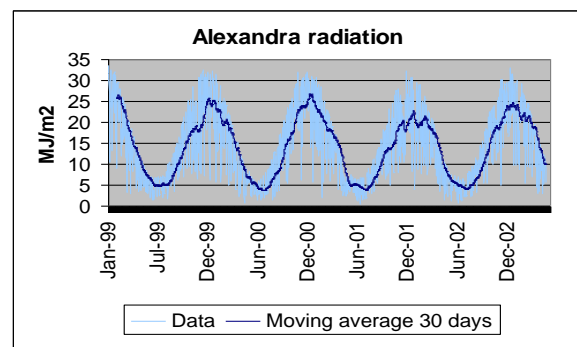
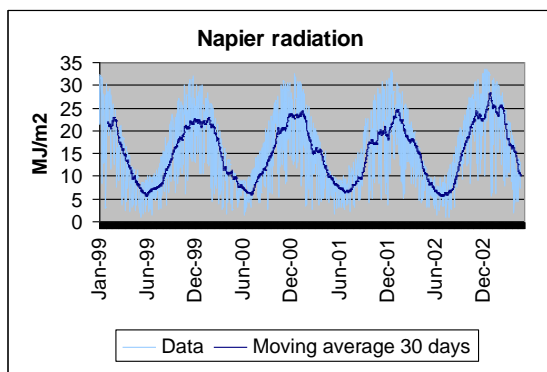
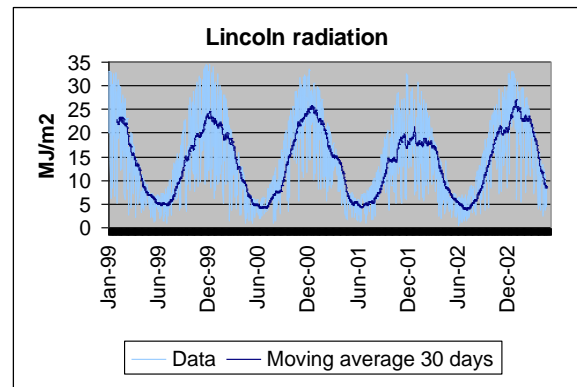
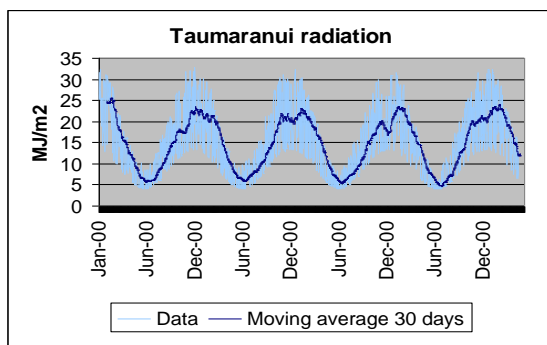
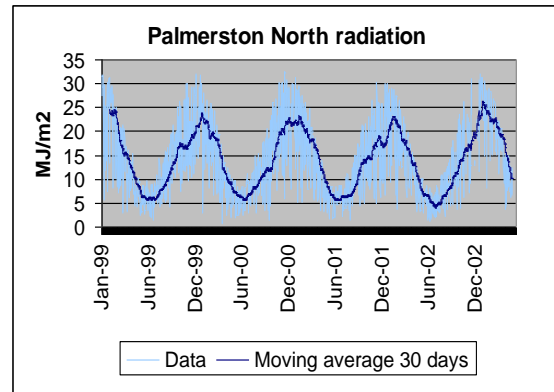
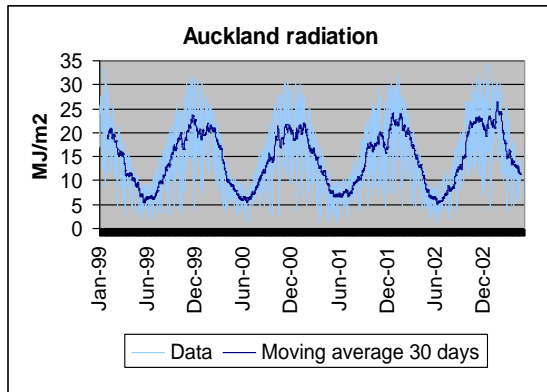
Clone	Mapiu	Rissington	Windwhistle
Shinsei	14.15ab	17.99ab	16.64ab
Blue/Brown	14.92ab		17.07ab
Blue/Green	14.86a	18.26a	15.60ab
Blue/Orange	12.79abc	18.08ab	11.42abc
Blue/Red	12.91abc	11.92abc	10.41abc
Weraiti	12.03abc	11.99abc	17.56ab
Selwyn	11.20abc	9.49bc	14.14ab
Otahuao	12.55abc	10.38abc	15.57ab
Toa	15.34ab	17.44ab	14.83ab
Dudley	12.19abc	10.60abc	13.73abc

Table 10. Ranking for each experimental clone for height and DBH at each site in each year based on the data in tables 8 and 9. Shinsei, as a commercial maxi-nigra clone, is included for comparative purposes.

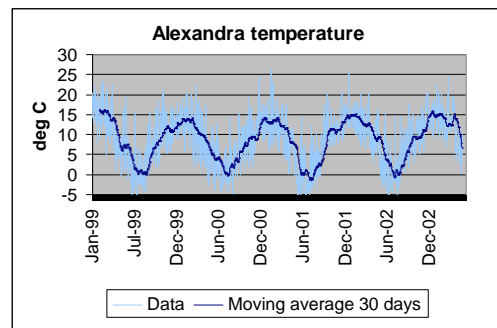
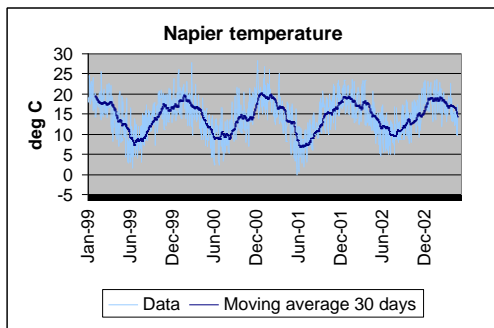
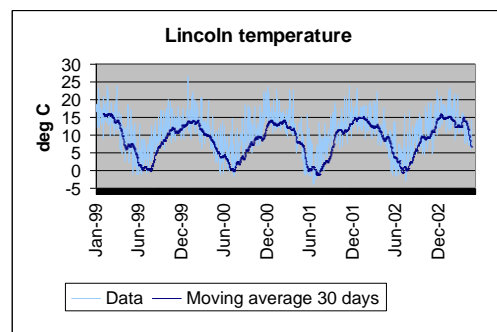
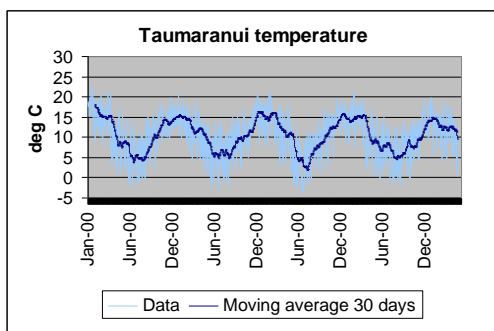
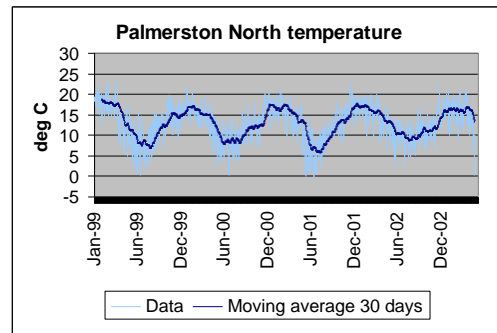
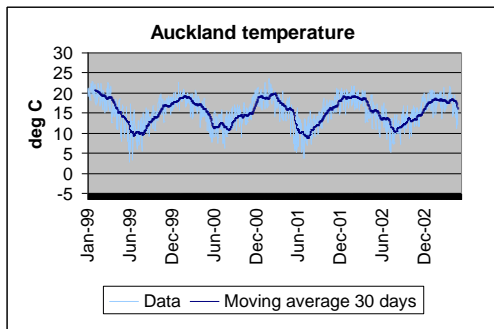
Clone	Year	Parakai		Mapiu		Rissington		Ashhurst		W'whistle		Millers Flat		All sites	
		hgt	DBH	hgt	DBH	hgt	DBH	hgt	DBH	hgt	DBH	hgt	DBH	hgt	DBH
Shinsei	1999			4	3	4	2			3	4			3	2
	2000	8	8	5	2	7	7	4	1			1	1	4	3
	2001	7	8	3	2	5	3	4	1			7	3	4	2
Blue/brown	1999			3	4					4	2			2	3
	2000	7	6	6	5	10	8	10	6			2	9	10	7
	2001	10	5	4	3	10	9	1	10			6	6	6	8
blue/green	1999			1	1	2	3			1	2			1	1
	2000	5	5	1	1	1	4	3	4			3	5	1	1
	2001	3	3	1	1	1	2	9	5			2	6	2	2
blue/orange	1999			2	2	1	8			5	6			6	5
	2000	9	9	2	3	8	9	5	3			4	7	6	6
	2001	2	2	6	6	4	4	8	6			7	8	3	4
blue/red	1999			8	7	7	9			6	5			10	9
	2000	10	10	4	6	6	10	9	10			5	10	9	10
	2001	8	9	7	5	8	9	3	9			3	7	5	10

## Appendices

Appendix 1 Radiation data recorded at the nearest weather station to each trial site  
January 1999 - December 2002.



Appendix 2 Temperature data recorded at the nearest weather station to each trial site January 1999 - December 2002.



Appendix 3. Daily rainfall recorded at the nearest weather station to each trial site  
January 1999 - December 2002.

