THE EFFECTS OF CYCLANEUSMA INFECTION ON TREE GROWTH

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EXECUTIVE SUMMARY

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Crown health was assessed over three years in a response surface silvicultural trial at Kaingaroa forest, over three years to determine the effect of stocking and pruning on the incidence and severity of *Cyclaneusma minus* infection. Individual tree growth measurements were analysed to establish the relationship between the severity of Cyclaneusma infection and diameter and height increment in both pruned and unpruned elements of the stand.
Neither tree stocking or pruning had any practical effect on incidence or severity of Cyclaneusma needle-cast.

Infection levels varied from season to season, depending upon weather conditions. However there was a trend towards increasing incidence and severity of infection as tree age increases.
Infection levels less than 25% of the green crown were shown to have little effect on DBH increment.
Infection levels above 30% affected diameter annual increment by between 0.3 and 0.6 cm (10-20%).
Cyclaneusma infection had no significant effect on height increment.

INTRODUCTION

Bulman (1995) demonstrated that trees severely infected with Cyclaneusma needle cast had significantly less diameter growth than paired 'healthy' trees. He found that after six years of infection at an average of 80% of the crown, volume increment was 50% of that of healthy trees. Bulman also reported that selective thinning, on the basis of disease resistance, reduces the incidence of diseased trees and results in increased tree growth.

In 1997 the Forest & Farm Plantation Management Cooperative agreed to a crown health survey being carried out on key silviculture trials. The assessment focussed on quantifying the incidence and level of infection of *Cyclaneusma minus* and *Dothistroma pini*. Assessments have continued each spring for the succeeding four years on a number of trials and representative growth plots on farm sites. The objective is to provide quantitative data to explain differences in growth rate due to crown disease. This paper analyses the effects of Cyclaneusma on diameter and height increment at the Kaingaroa followers trial (FR 274).

METHODS

The trial in compartment 1009 at Kaingaroa Forest in was planted in 1990. It is a response surface design consisting of sixteen 0.0300 ha treatment plots with 0.1000 ha measurement plot. Each plot has a core treatment of 270 stems/ha pruned to 6.5 metres in 3 lifts with between 100 - 360 stems/ha of followers which will be thinned at a range of Mean Top Heights. Generally some pruned trees have been dropped out at each pruning lift so there are "intermediate" followers i.e. P1 followers are pruned to 1.5 - 2.7 metres and P2 followers are pruned to 2.8 - 4.8 metres. These partially pruned elements generally amount to 70 stems/ha or less. Throughout the period of this study tree stocking ranged from 350 sph to 630 sph. The treatments represented are shown in table 1.

Table 1: Typical regimes by treatment.

	Stems / ha per treatment									
	Crop	Follower	Crop	Follower	Crop	Follower	Crop	Follower	Crop	Follower
No planted	1200		1200		1200		1200		1200	
1st prune (2.4m)	350	23	350	60	350	150	350	240	350	277
2nd Prune (4.2m)	300	50	300	50	300	50	300	50	300	50
3rd Prune (6.5m)	275	25	275	25	275	25	275	25	275	25
Total		98		135		225		315		352
MTH at final thinning (m)		18.0		14.0 22.0		12.0, 18.0, 23.6		14.0 22.0		18.0

All plot trees were assessed for disease in October 1997, 1998, and 1999. The method of Kershaw *et al.* 1988 was followed where the proportion of crown showing symptoms of *Cyclaneusma* to uninfected green crown was estimated and given as a percentage. Needle loss due to suppression or previous years' infection was ignored. Trees showing no symptoms of disease were graded '1' to confirm that they had been assessed. All data was recorded on the PSP system using Husky Hunter data loggers.
Annual measurements of DBH for all trees and, height and crown height for a sub set, were made each July throughout the study period.

The crown health score was related to the increment period in which it fell e.g. the crown health score from October 1998 related to the diameter increment from July 1998- July 1999.

Differences between treatments were tested by performing stepwise regressions and undertaking analyses using generalised linear models (McCullagh & Nelder 1989).

RESULTS

Disease levels of the pruned-crop trees were significantly lower than the unpruned and partially pruned followers in 1997 and 1998 ($p<0.0001$). In 1997, pruned crop trees had average disease severity of 1.7 % compared with 10.9% for followers. In 1998 disease averaged 14.8 % and 22.5% for pruned crop trees and followers, respectively. In 1999 and 2000 there was no significant difference between pruned-crop trees and followers. The mean infection levels for each crop element are presented in Table 2.

Table 2: Infection levels by year and stand element.

	Percentage of crown infected			
Stand element	**1997**	**1998**	**1999**	**2000**
Unpruned followers	10.9 % a*	22.5% a	14.6 a	14.8 a
Pruned Crop trees	1.7 % b	14.8% b	13.2 a	14.3 a

* In the same year values with the same letter are not significantly different (P= .05)

The incidence of Cyclaneusma by infection class is shown in Table 3.

Table 3: Incidence and infection levels by year

	1997		1998		1999		2000	
% infected	**n**	**Mean**	**n**	**Mean**	**n**	**Mean**	**n**	**Mean**
0-5	599	2.0	223	4.8	193	4.6	287	4.8
10-15	125	11.5	267	12.3	325	12.1	204	12.0
20-25	34	21.8	111	22.0	108	21.4	83	22.5
30+	15	40.3	167	45.6	94	40.7	98	49.4
Total	773	5.2	768	18.8	720	15.2	672	15.7

In 1997 (tree age 7) the mean infection level was low (5.2%). This increased dramatically to 18.8% in 1998 and has stabilised at 15-16% in the two succeeding years. The percentage of trees showing high infection levels is increasing with tree age. In 1997 2% of trees had greater than 30% of the crown infected whereas in 2000 this had increased to 15% of trees.

The effect of infection level on DBH increment and height increment is summarised in table 4 and figure 1. DBH increment is not significantly affected at low levels (< 20%) of crown infected. At levels above 30% infection there is a reduction in DBH increment of between 0.29 and 0.55 cm or 9-20%. However the differences were only significant in the 1998/99 year.

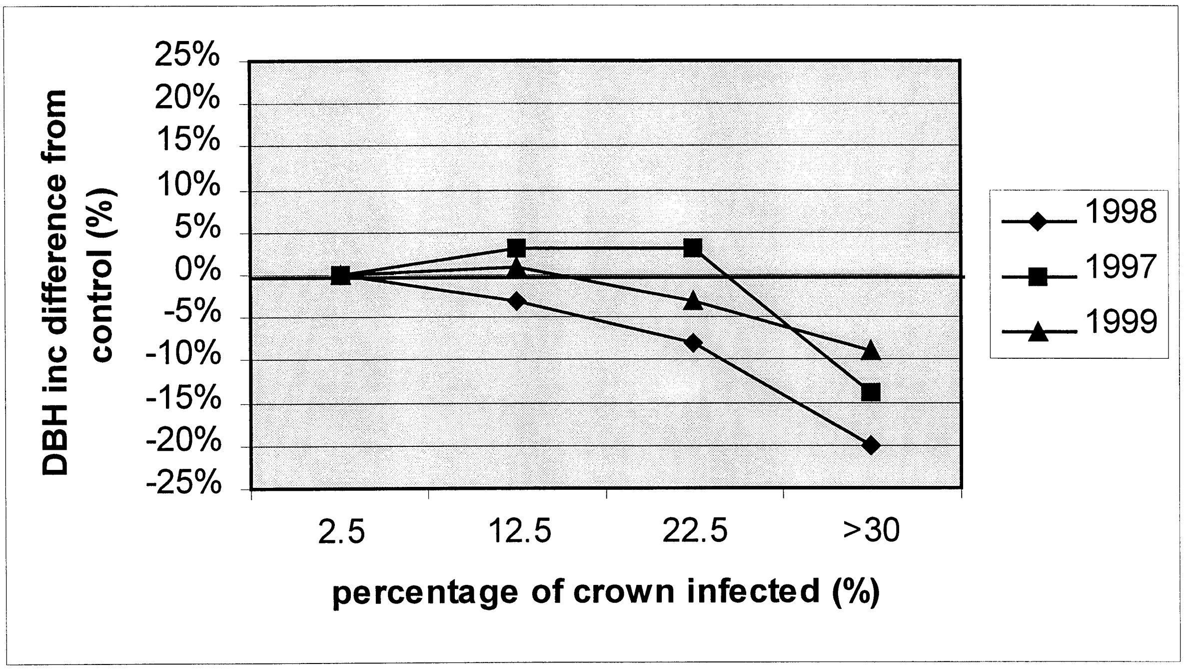
Table 4: Affect on tree diameter and height increment

	Diameter increment (cm)		
Infection level	**1997-98**	**1998-99**	**1999-2000**
0-5 %	2.83 a*	2.54 a	2.67 a
10-15%	2.92 a	2.46 a	2.68 a
20-25%	2.92 a	2.33 ab	2.57 a
30%+	2.43 a	1.99 b	2.38 a
	Height increment (metres)		
	1997-98	**1998-99**	**1999-2000**
0-5 %	1.86 a	2.23 a	1.99 a
10-15%	2.07 a	2.11 a	1.98 a
20-25%	1.80 a	2.14 a	1.94 a
30%+	1.88 a	1.94 b	2.06 a

- In the same year values with the same letter are not significantly different (P= .05)

The data showed no significant difference in height increment attributable to Cyclaneusma infection.

Figure 1: Percent difference in DBH Increment relative to crown infection level



DISCUSSION

These results are consistent with previous work (Bulman 1995 and Bulman & Dean 2000). The biology of *Cyclaneusma* is different from other foliar fungi, such as *Dothistroma pini*, where pruning and stocking treatments have been shown to affect disease severity. *Cyclaneusma* spores are produced on cast foliage on the forest floor and dispersed during periods of rainfall with maximum spore release occurring after five hours of rain. There is ample inoculum during the months when foliage is susceptible to infection. *Dothistroma* spores are also dispersed during periods of rainfall but, in contrast to *Cyclaneusma* spores, are produced on infected needles still attached to the tree. The removal of foliage infected by *Dothistroma* from the tree therefore reduces the amount of inoculum available, because needles on the forest floor, particularly in unthinned stands, quickly become colonised by saprophytic fungi which limits *Dothistroma* spore production (Gadgil 1970). Pruning foliage infected by *Cyclaneusma* will not lessen disease severity because spores are not produced on needles attached to the tree. *Dothistroma* infection is dependent on leaf surface moisture and such conditions are prevalent in densely stocked stands where reduced airflow results in foliage remaining moist for longer periods than in stands that have been pruned and thinned. Gadgil (1974, 1977) has shown in growth chamber studies on *Dothistroma* that increasing the leaf wetness period significantly decreased the pre-production period (the time elapsed from inoculation to appearance of spores) and resulted in increased infection. *Cyclaneusma* infection is not reliant on long periods of needle moisture but on the frequency of wet periods of about 5 hours duration.

When frequent short wet periods occur in autumn and winter, heavy *Cyclaneusma* infection can be expected. Rainfall for the May - July period was 441 mm, 608 mm, and 415 mm for 1997, 1998, and 1999 respectively. The proportion of trees with disease levels greater than 50% was significantly higher in 1998 than 1997 or 1999 (Table 5). However in 2000 the proportion was near 1998 levels. This may result in significant differences in DBH increment in the 2000 -01 period.

The difference in disease levels of the pruned crop trees and followers, while statistically significant, were small in practical terms. If one examines the proportion of trees within each treatment exhibiting disease levels of 50% or more (i.e., trees that would be subject to significant growth loss), there is little difference between follower and crop elements (Table 5). Unpruned trees will be assessed as having higher disease levels than pruned trees because disease generally develops in the mid and lower crown, therefore the proportion of diseased foliage to green foliage on an unpruned tree will be higher than on a pruned tree. It is the removal of infected foliage from view that results in lower disease levels recorded on pruned trees, and not the effect of removal of inoculum.

Table 5: Proportion of trees in each treatment with disease levels assessed at 50% or greater.

Year	Trees assessed with disease levels 50% or greater (percent of total)	
	Final-crop	Followers
1997	0.5	1.0
1998	7.3	9.0
1999	3.4	2.2
2000	4.9	5.1

CONCLUSIONS

Tree stocking or pruning had no practical effect on incidence or severity of Cyclaneusma needle-cast because the infection process of *C. minus* is dependent on the frequency, and not length, of needle moisture periods. Disease levels below 25% of crown infected do not result in measurable reduction in diameter increment. However, at disease levels above 30% of crown infected significant reductions in diameter growth can be expected.

Delayed selective thinning can be used to reduce the impact of the disease. 'Plant and leave' regimes provide no opportunity to thin susceptible trees.

On disease prone sites it is likely that a traditional regime of planting more trees (800-900 sph) and carrying out a thinning after age 7 to remove susceptible trees will be economically beneficial.

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