

Pine Needle Blight

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EXECUTIVE SUMMARY

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Objective

The objective of this work was to investigate the hypothesis that physiological needle blight in *Pinus radiata* is caused by needle water stress, in particular:

- the effect of environmental conditions on winter and spring root and needle water potentials
- the effect of tree age and branch height on needle water relations and branch water conductance.

Key results

- Increasing soil water moisture was associated with an increase in root water potential
- Daytime needle water potentials ranged from approximately -0.3 to -0.9 MPa
- Water loss from open stomata was greater in needles from 16-year-old trees than 6-year-old trees, but tree age had no effect upon needle water potential
- Resistance to water flow was higher in branches of 16-year-old trees than in branches of 6-year-old trees.

Application of Results

Evidence is building to support the hypothesis that Physiological Needle Blight (PNB) is the result of a culmination of specific environmental conditions and age related changes in tree physiology that result in water stress to the needles.

Further Work

More data will be gathered to support the hypothesis, with a focus upon trees particularly vulnerable to PNB. The hypothesis will also be expanded to consider the mechanism behind the needle water stress.

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INTRODUCTION

Physiological Needle Blight (PNB) is known to occur in *Pinus radiata* plantations in late winter/early spring. The phenomena affects trees of about 15 years and older; the foliage turns red brown but remains firmly attached to the tree after needle death. The trees remain alive and new growth occurs in the months following the needle blight. In many cases large areas within a plantation are affected covering hundreds of trees across a hillside or through gullies (Bulman 2002). In many cases needle blight outbreaks have been associated with high mid winter rainfall and non porous soils.

Given these observations, this work investigated the hypothesis that PNB is caused by needle water stress. Needle water status can be affected in 3 ways: water uptake to and transfer from the root; pathway resistance from root to shoot; and water loss from needles.

Measurements of root and shoot water potential were taken in 16+-year-old trees growing in high and low soil water contents, in mid winter (August) and early spring (October), to investigate the effect of soil water content and time of year upon water uptake and needle water status.

Branch and needle water conductance was measured in trees aged 6 and 16 years, to investigate the effects of age upon water flows to needles and water loss from needles.

MATERIAL AND METHODS

ROOT AND NEEDLE WATER POTENTIALS

Two plantations were selected for the root and needle water potential measurements on the basis that the areas had been previously prone to PNB outbreaks. The first plantation was a Carter Holt Harvey forest on Allan Road, off Mangakahia Road between Whangarei and Kaikohe. The second plantation, owned by Juken Nissho Ltd, was 30 km south of Gisborne on SH2. Two study sites were selected within each plantation. One site was selected for its high soil moisture content (treatment). A control (low soil water content) sites was also selected. Sampling took place in August and October 2005.

Needle water potentials were measured using a pressure bomb (on single needles (24 needles per treatment) sampled from approximately 4 m above the ground between midday and 4 p.m. Root water potentials were estimated from needle water potential measurements taken pre-dawn (3-7 a.m.), assuming equilibrium of water at night.

Two soil samples were collected at each site below the sampled trees and the water content was calculated as percentage weight loss following drying of samples.

TISSUE CONDUCTANCE AND NEEDLE WATER LOSS

To investigate the effect of tree age upon water flow resistance through the branch to the needles and needle water loss, two stands of trees were selected, one aged 6 and the other 16 years old. The two stands were located next to each other with a NW aspect. Branches and needles were sampled at 3-4 m height above the ground from both sets of trees. To study the effect of branch height, further samples were taken at 14-15 m height from the 16-year-old trees. Sampling occurred on a sunny, dry day.

Needle water potentials were measured using a pressure bomb. Needle water loss due to stomatal or cuticular conductance was measured by sealing individual needles into a 25 μ l Eppendorf tube with a reservoir of 20 μ l and measuring weight loss over 3 days (Figure 1). Needles were kept at 20°C at 50% RH either in the dark (cuticular conductance) or light (stomatal conductance).

Branch conductivity was measured using a high pressure flow meter (HPFM; Dynamax Inc. Houston). Branches were selected with two segments: segment 1 defined as the youngest branch furthest from the tree which had 1 year old needles growing from it, and segment 2 was the older branch to which segment 1 was attached.

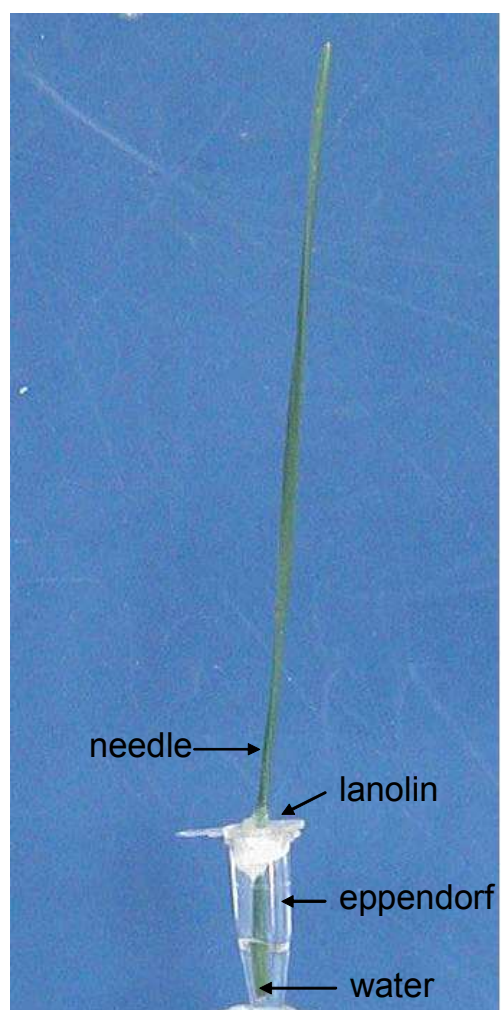


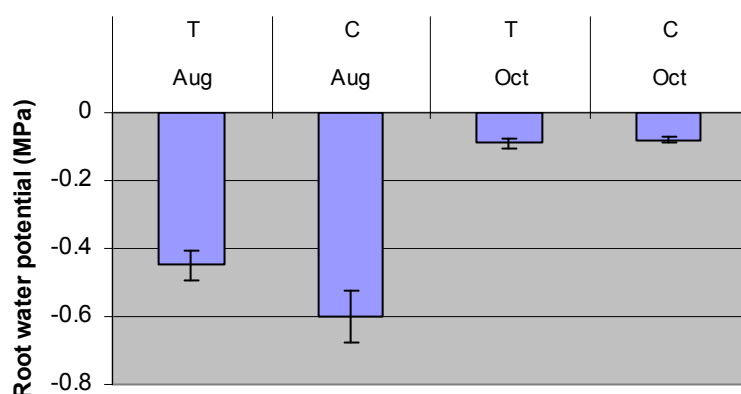
Figure 1: *Pinus radiata* needle sealed in Eppendorf tube used for water loss experiments.

RESULTS

Root water potentials ranged from -0.6 to -0.09 MPa (Figure 2). At both the Northland and Gisborne sites the water potential was lower in August than in October. There was no difference in water potential between the treatment and control sites except in August at Northland. The August root water potential measurements taken in Northland were significantly lower than the other root measurements (T-test; $P < 0.05$). Heavy rain and cold temperatures at the time of sampling made accurate measurements difficult and are likely to be responsible for the unusually low water potential measurements made at this time. As a result these data were removed from further analyses.

At the time of root water potential measurements, soil water content was measured and correlated to the water potentials (Figure 4). As expected there was a clear relationship between root water potential and soil water content ($r^2 = 5.9$).

a)



b)

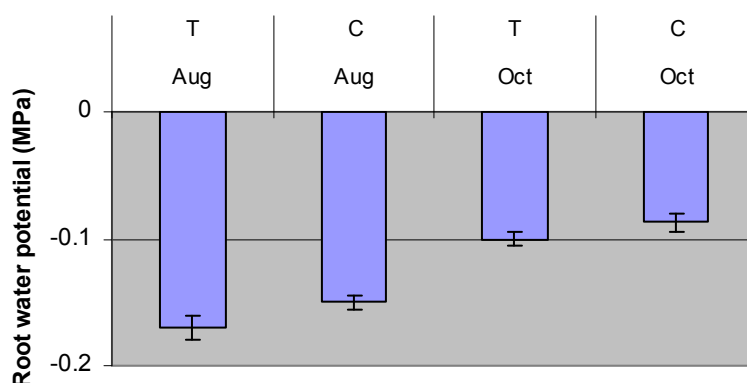


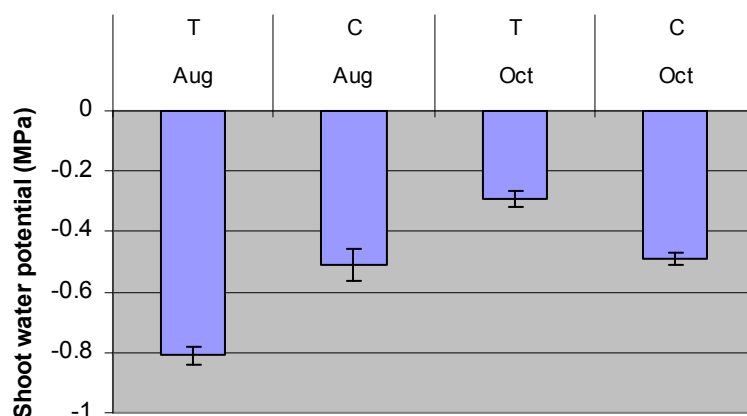
Figure 2: (a) Root water potential (MPa) measured in treatment (T) and control (C) *Pinus radiata* trees in (a) Northland and (b) Gisborne. Measurements were taken in August and October 2005. Standard error bars shown, $n = 24$.

Needle water potentials measured between midday and 4 p.m. were much more variable than the root water potentials (Figure 3). The lowest water potentials (-0.9 MPa) were measured in Gisborne on a clear sunny day. The highest measurements (-0.3 MPa) were measured in Northland again on a clear sunny day. In fact, in at the Northland treatment site, significantly lower water potentials were measured in August in the rain than in October in the sun

($p < 0.05$). In contrast, there was no difference between the August and October controls in Northland (T-test; $P > 0.05$).

In Gisborne, October needle water potentials were higher than those in August for both control and treatment sites (T-test; $P < 0.05$). There was no correlation between needle water potential and soil water content (Figure 4b).

a)



b)

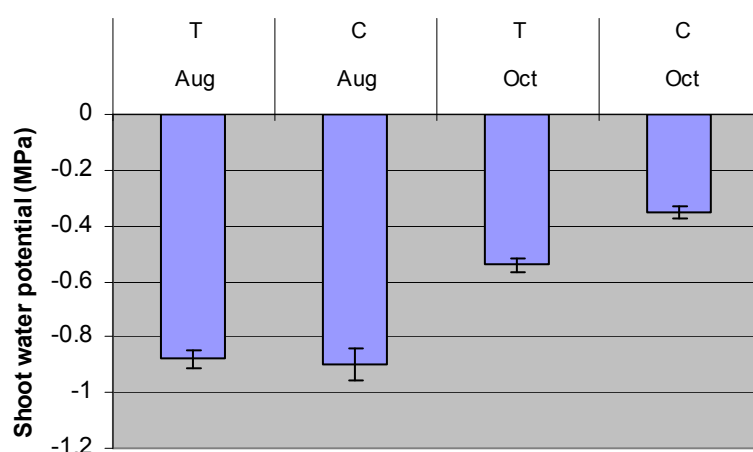
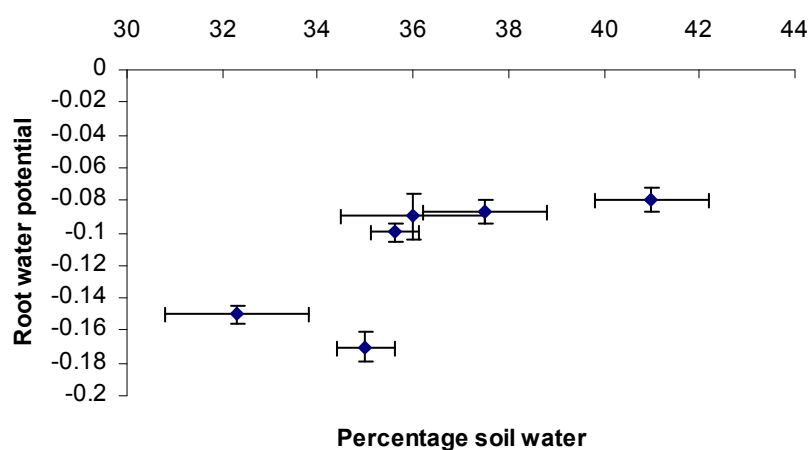


Figure 3: (a) Shoot water potential (MPa) measured in treatment (T) and control (C) *Pinus radiata* trees in (a) Northland and (b) Gisborne. Measurements were taken in August and October 2005. Standard error bars shown, $n = 24$.

a)



b)

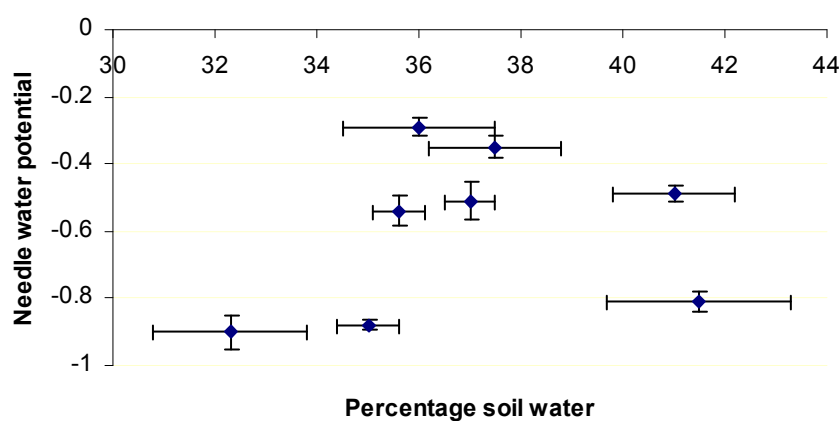


Figure 4: Water potential plotted against soil water content in *Pinus radiata* a) roots and b) needles. Standard error bars shown.

To investigate the effect of root water status on needle water status, the root water potential was plotted against that of the shoot for each individual tree (Figure 5). Needle water potential increased as root water potential increased.

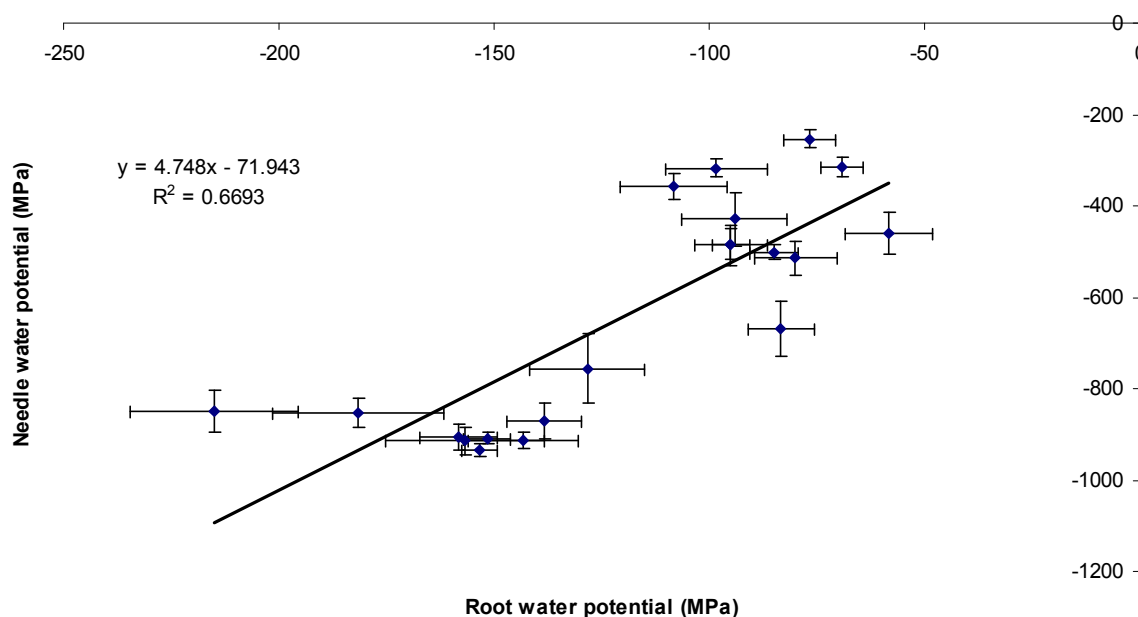


Figure 5: The relationship between root water potential and needle water potential for each individual *Pinus radiata* tree at each site (Gisborne and Northland, 2005). Standard error bars shown (n=6).

To investigate any impact age may have had on the susceptibility of the tree to PNB, branch and needle water relations were examined in 6- and 16-year-old trees. Tree age had no effect on needle water potential or on cuticular conductance; neither did tree height (Figures 6 & 7). In contrast needles collected from 15 m height above the ground on the 16-year-old trees had a higher stomatal conductance than those collected from 4 m on the same tree or those collected from 6-year-old trees (Figure 7; T-test; $P < 0.05$).

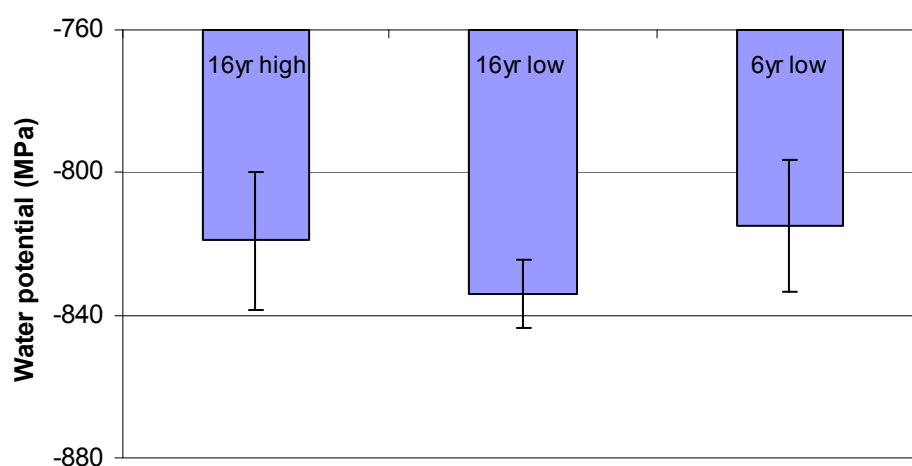


Figure 6: Water potential of needles taken from 16-year-old or 6-year-old *Pinus radiata* trees. Needles were sampled from 3-4 m (low) and from 14-15 m (high) above the ground. Standard error bars shown (n=10).

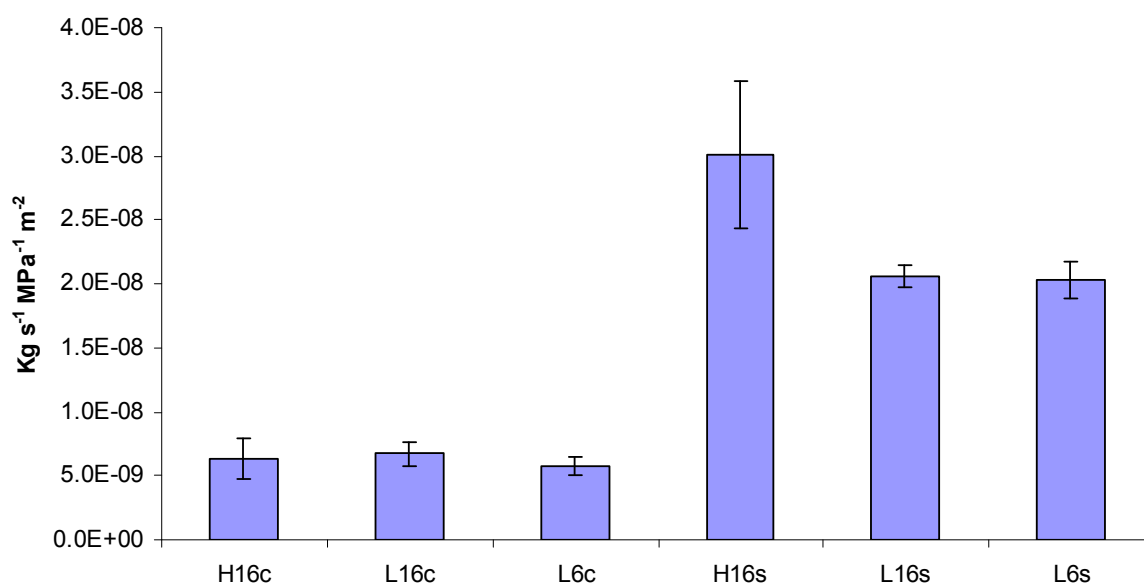


Figure 7: Stomatal (s) and cuticular (c) water conductance from *Pinus radiata* needles harvested from 16-year-old (16) and 6-year-old (6) trees. Samples were collected at 3-4 m (L) and 14-15 m (H) above the ground from the 16-year-old trees. Standard error bars shown (n=20).

Branch water conductance was measured in the youngest branch connected to the needles (segment 1) and in the next oldest branch attached to segment 1 (segment 2). In the 6-year-old trees, there was no difference in conductance between segment 1 and segment 2 (Figure 8). In the 16-year-old trees, however, segment 1 had a significantly reduced conductance compared with segment 2. Branches from 16-year-old trees had a lower conductance than those from 6-year-old trees (T-test; $P < 0.05$). There was no effect of branch height on conductance.

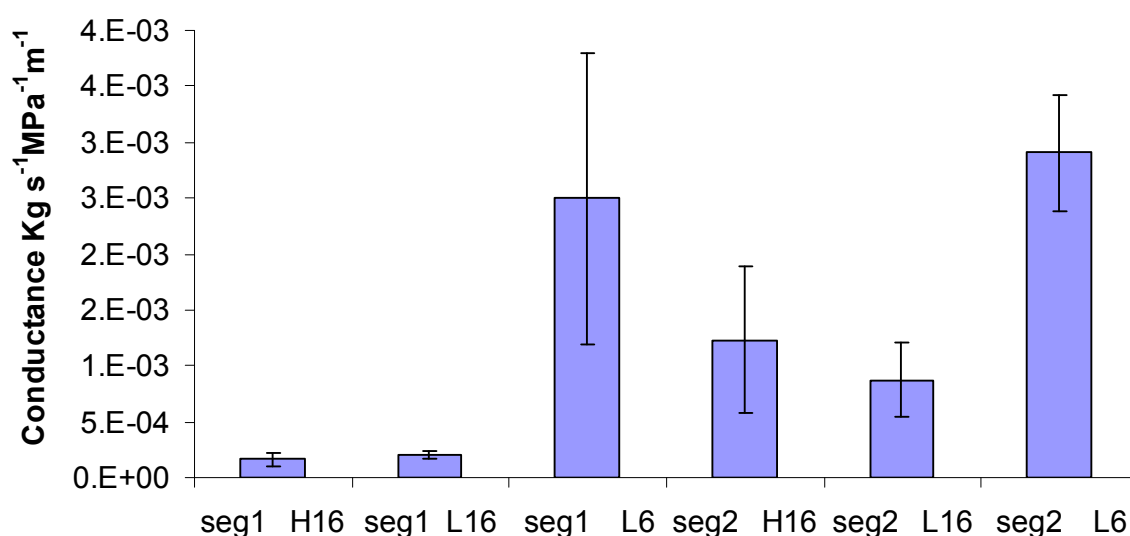


Figure 8: Water conductance of segment 1 (seg 1) and segment 2 (seg 2) branches collected from 16- and 6-year-old *Pinus radiata* trees. Branches were collected at either 3-4 m (L) or 14-15 m (H) above the ground. Standard error bars shown (n=5).

DISCUSSION

Experiments were carried out to test the hypothesis that physiological needle blight (PNB) is caused by water stress to the needles in early spring. It is thought that a number of factors may contribute to this water stress. High rainfall during winter, and early spring low soil temperatures can limit root growth and development, inhibiting water uptake. These factors when combined with high air temperature (in comparison with soil temperature) and high irradiance in early spring can lead to water loss from the needles. Thus midwinter and early spring water potentials were measured in the roots and needles. Unsurprisingly, root water potential was related to soil water content, although the relationship was not linear. At high soil water contents, water potential remained constant, suggesting a mechanism within the roots to limit water uptake when saturated. A close relationship was also observed between root and shoot water potential, suggesting a decline in root water potential may reduce needle water potential. Thus, any loss of root function, perhaps caused by a breakdown in the mechanism protecting roots from water logging, would adversely affect needle water status. Aquaporin function within roots has been shown to reduce with anoxic stress (Tournaire-Roux et al. 2003), and such a mechanism in pine trees would limit water flow root to shoot, contributing to needle water stress. Needle water potential varied greatly and in most cases could be explained by the weather conditions at the time of sampling. During our sampling period we did not measure any water potentials that were indicative of water stress, but neither did the trees show signs of PNB.

To date, PNB has only been observed in trees aged 15 years and older. A possible explanation of this is a change in the water conductance and water relations as trees grow older (and taller). As trees grow, water pathways to the needles grow longer, resistance increases and a greater water potential difference root-shoot is required to pull the water along these pathways and to greater heights. It is hypothesized that increases in water potential differences between the roots and shoots coupled with increasing pathway resistances in older trees can induce embolisms to enter the xylem, thus inhibiting the flow of water to the needles. In this work, the effect of tree age and height on branch and needle water conductance was measured to examine its possible contribution to embolism formation. Water conductance was measured in the two branches closest to the needles (segments 1 and 2). The 6-year-old trees showed no difference in water conductance between the two segments and had a higher conductance than the branches from the 16-year-old trees. Conductance reduced in the branch segments closer to the needles compared with branch segment 2. These results fit the hypothesis that older trees are more vulnerable to embolism formation because of a high resistance pathway.

Water loss from cuticular conductance was not affected by age of needles or sampling height, suggesting cuticular wax thickness does not play a role, but stomatal conductance was greater in needles sampled from 15 m than from 4 m above the ground. The increased stomatal conductance may be required to create the extra water potential difference required in turn to pull water the extra height. There was no effect of tree age on stomatal water conductance.

CONCLUSIONS

This work goes some way to examining a hypothesis on the cause of PNB in *Pinus radiata*. It highlighted the close relationship between root water potential and needle water potential, and how this relationship and thus water uptake to the needles, are dependant upon the control mechanism of water uptake by the roots. We were also able to highlight physiological differences in water conductance between different aged trees, which can explain the differences in susceptibility to PNB of different aged trees.

RECOMMENDATIONS

Further work is required to test the hypothesis that PNB is caused by water stress in the needles, and that this water stress is a result of embolism formation in the xylem vessels prior to the needles.

Water potential measurements on trees that have recently shown PNB symptoms are required (or even better measurements on trees that go on to develop PNB). In addition, given the differences in physiology with age, the vulnerability of different aged trees to xylem cavitation should be investigated.

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