Project Record No. 3125

MID-CROWN YELLOWING (MCY): CURRENT STATUS OF KNOWLEDGE AND RESEARCH OPPORTUNITIES. DISCUSSION DOCUMENT

by

P.N. BEETS

Report 55 May 1992

MID-CROWN YELLOWING (MCY) : CURRENT STATUS OF KNOWLEDGE AND RESEARCH OPPORTUNITIES - DISCUSSION DOCUMENT

P. N. Beets

Summary

Upper mid-crown yellowing in radiata pine is thought to be the result of magnesium deficiency, and if this proves to be correct then careful consideration needs to be made of the potential implications of this finding because:

1) Foliar magnesium levels in radiata pine are marginal in a large proportion of New Zealand's radiata plantations.

2) The situation is likely to get worse because nutrient removal during harvesting affects Mg proportionally more than most other nutrients, and this situation holds true at all levels of harvesting intensity.

3) Growth losses are marked when Mg deficiency is critical, as was demonstrated in Southern Kaingaroa.

4) Mg is often not readily available to radiata pine because its Mg uptake capability is poor compared to other species, and its recovery following fertiliser application can be very slow in stressed trees.

5) Typically the dominant trees in affected stands show MCY symptoms, and tree selection for breeding or other propagation purposes should directly consider genetic differences in nutritional traits to avoid accentuating the problem; presently this is not the case.

The total mineral reserves of Mg are usually ample in the soil, and a possible alternative or addition to the use of fertiliser involves improving the nutritional traits of radiata pine. The scope for improvement of nutritional traits is good because:-

1) Large genetic differences exist in Mg uptake by radiata and perhaps also in utilisation of Mg and other nutrients.

2) Dominant trees in stands with MCY do not all exhibit MCY symptoms.

3) The limited amount of clonal information available indicates that radiata clones exhibiting MCY symptoms in older stands have low foliar Mg levels at a younger age.

Given the above, it is suggested that the focus of future research related to MCY be on increasing our understanding of the basis for genetic differences, and developing techniques for capitalising on this understanding. These steps are essential in designing systems for treating affected stands, and in seeking ways to better adapt future stands of radiata to New Zealand soils and management systems.

Background

MCY is a disorder of radiata pine currently being investigated by FRI with the aim of quantifying growth losses and thereby establishing the economic importance of MCY. The disorder occurs widely throughout both islands of NZ, primarily in inland areas. Initial investigations point to a nutritional stress involving primarily magnesium limitation as the most likely cause (Beets *et al.*, 1991).

Past and present government and industry funded research related to MCY is examined with the view to define areas warranting further research and collaboration. The aims are to better understand the disorder and to develop and test methods for treating existing stands and improving future stands.

This document is based on input from a working group, and the findings are presented here for discussion.

<u>Magnesium deficiency - current situation</u>

Magnesium deficiency is of increasing concern both nationally and internationally. The evidence and possible reasons for this trend include the following.

The problem is widespread

Magnesium deficiency is experienced in Germany (Roberts *et al.*, 1989) among a number of countries, where the Ca and Mg foliar concentrations decline markedly in the upper parts of older trees. High inputs of atmospheric N in acid rain in Europe has promoted shoot growth while enhancing cation leaching in the soil. Where atmospheric inputs of Mg are low, as occurs inland (away from sea spray which has high Mg concentrations), nutritional health problems and tree decline result if soil Mg availability is low.

Decline symptoms occur in radiata stands throughout inland NZ, either as Mg deficiency symptoms in young stands or as upper MCY symptoms in older stands. Mg requirements attain up to 20 kg/ha/year in radiata stands (based on unpublished nutrient concentration data and dry matter data in Beets and Pollock, 1987; Madgwick et al 1988). This compares with atmospheric inputs of only around 1kg/ha/year inland but 5-9kg/ha/year at coastal sites (Hodgkiss, unpubl.). Most of New Zealand's plantation forests are located inland where foliar Mg levels are often marginal (Hunter *et al.*, 1991).

Dominant trees typically show MCY symptoms

Not all trees in the stand are equally affected. While co-dominant trees can exhibit MCY symptoms, it is of particular concern that the disorder is often evident in the dominant trees in affected stands. This is curious because normally one might expect a nutrient limitation to reduce growth relative to unaffected neighbours. However, Madgwick *et al.* (1988) found lower foliar and stem bark Mg concentrations in canopy dominants compared to trees in lower crown classes, based on individual tree analyses. MCY in canopy dominants is disturbing because in severe cases tree tops die back, and future stand growth then depends on the subdominant trees attaining dominance.

MCY is difficult to observe from the ground in closed stands, and therefore the selection of dominant trees for tree breeding or cloning may unwittingly increase the incidence of MCY unless nutritional traits are considered.

Magnesium nutrition and growth

Trees often respond rapidly to N in fertiliser response trials, but slowly or imperceptibly to cations such as Mg, and the importance of Mg may be underestimated. Why? The above ground response to N fertiliser is believed (perhaps incorrectly) to involve initially a change in partitioning of growth from roots to shoots. This gain in above ground growth is then further accentuated by greater tree productivity owing to the higher leaf area. In contrast, Mg fertiliser seems to increase root growth of deficient trees (and perhaps allocation below ground), followed by a slow improvement in foliar nutrient status over the next few years. Increased stem growth is evident several years after the initial fertiliser application, but the most observable benefit from the Mg is improved health of the trees, which show less crown mortality of needles and twigs in the upper crowns (Hunter *et al.*, 1986; Beets *et al.*, 1991).

Genotype-environment interactions can make interpretation of findings difficult

Burdon (1976), in a study of 18 clones growing at four contrasting sites, found that foliar nutrient concentrations were not correlated with tree growth rates (tree size), and therefore concluded that foliar analysis was not a reliable indicator of growth potential. This conclusion is not consistent with the results of Madgwick *et al.*(1988), who show a correlation between tree size and Mg concentration in seedling origin trees. But what is the explanation for these findings?

Beets (unpublished data), in a study of 6 clones at four contrasting spacings, found that the performance of genotypes was related mostly to spacing and to a lesser extent by genetics. Performance of these genotypes is therefore a function of the growth strategy and hence competitive ability of the genotype. Rapid early shoot growth is critical for trees to compete for light at high stocking levels. If this growth strategy is associated with poor rooting or one with low root uptake efficiency nutrient dilution could occur. The outcome then would be a poor or even negative correlation between foliar chemistry and tree performance.

Rooted cuttings show MCY has a genetic basis, and Mg is involved

While tree performance (size) need not be related to foliar chemistry, the health and vigour of genotypes is. Clones 448 and 450 had the highest (0.14%) and lowest (0.09%), respectively, foliar concentrations of Mg in the 4 year old physiologically young 'Long Mile' stand (Table 1). Marked Mg deficiency symptoms were evident in 450 owing apparently to high translocation from older needles (Knight 1978), and variation within clones was small. The correlation between Mg concentration measured by Knight (1978) and MCY severity observed in the 18 year old stand at Puruki is obvious. The correlation with physical damage is not (Table 1).

MCY syptoms are very consistent within a clone, and this high repeatability indicates that microsite differences are small. Hence, the large tree to tree differences in MCY symptoms that are evident in seedling origin trees must have a genetic basis. Why else would the ramets of a clone have almost identical symptoms over an area covering half a hectare, yet adjacent seedling origin trees have markedly different MCY severities.

Could B also be involved in MCY? Probably not directly, because clone 448 and 456 have the lowest (17ppm) and highest (32ppm) foliar B concentration, respectively in the study by Knight(1978), while neither clone showed MCY symptoms at Puruki. Some bud dieback in trees with MCY symptoms resembles B deficiency but this likely to be a secondary symptom. MCY trees have a lower moisture content than healthy trees, suggesting a loss in conductivity or stomatal control. It seems more likely that a severe Mg imbalance results in other nutrient uptake problems and the appearance of associated deficiency symptoms.

The propogation history of clones in the 'Long Mile' stand is documented in Knight(1978). Seed were sown in October 1963, cuttings taken from most vigorous seedlings in April 1964 (from 6-month old seedlings) and grafted to seedling rootstocks, cuttings taken in April 1965 from these 12-month old grafts, and in July

1966 successfully rooted cuttings lined out in nursery. In July 1967 the now 27-month old cuttings were planted in the 'Long Mile' stand. These clones were physiologically juvenile, so the behaviour of this material should be similar to seedlings.

Table 1: MCY severity, foliar Mg, and physical damage in ramets of Puruki Clones. (Y indicates ramets with damage, N without damage).

Clone	MCY Severity[1]	Foliar Mg (%)[2]	Possum damage	Comments
448	A+	0.14	3Y/IN	2 trees heavily chewed
450	C+	0.09	1Y/0N	Thinning damage, no chewing
451	A-	0.12	2Y/3N	small amount of chewing
454	B+	0.13	1Y/3N	1 tree with severe chewing

1 MCY severity codes defined in Beets et al.(1991)
2 Foliar Mg concentrations from Knight (1978)

Seedling origin trees also show that MCY is related to Mg deficiency

Decreasing foliar Mg concentrations coincide with an increase in the severity of MCY symptoms in seedling origin trees at Puruki (Beets *et al.*, 1991), providing independant confirmation of results obtained from the clonal material. The foliar chemistry results are based on samples taken from the top of the MCY zone.

The sampling location within the crown is critical. Mg concentrations decrease with height up the tree crown (Table 2), and samples from immediately below the MCY zone may indicate marginal Mg levels when in fact levels are critical higher up.

The sampling location within the stand is also critical. The proportion of trees exhibiting severe MCY (C and D classes) is highest in the northern part of the widely spaced Puruki-Tahi stand (Table 3). Heavy bracken occurs throughout the area. The explanation for the gradient in MCY must therefore be related to soil differences over the area, and water analysis supports this belief. Mg concentrations, measured monthly over many years (1979-84), are lowest in the stream draining the northern part of Puruki-Tahi (0.31mg/l), and are highest in stream draining Puruki-Toru

(0.53mg/l) which has a low incidence of MCY. Puruki-Rua has a moderate incidence of MCY and stream water concentrations of 0.35mg/l.

Table 2. Mean foliar magnesium concentrations in eight fertilised and eight unfertilised *Pinus radiata* trees with MCY severity codes of 'B' and 'C', in Puruki-Rua. No effect of fertiliser is evident even though the equivalent of 100kg/ha Mg as Epsom Salts (together with 200kg/ha calcium as calcium chloride and 6kg/ha boron as boric acid), was applied to individual trees in the stand in December 1990, and foliage analysed in October 1991.

Age Class	Crown position	Unfertilised	Fertilised
Current	Upper	0.044	0.047
	Middle	0.067	0.041
	Lower	0.085	0.075
Older	Upper	0.042	0.032
	Middle	0.046	0.036
	Lower	0.063	0.062

Mg translocation from older needles is 22% overall .

In some situations poor rooting and physical damage can lead to MCY symptoms. Occasional stream-side trees have MCY symptoms in parts of Puruki catchment which otherwise have a low incidence of MCY. In one such tree the MCY zone has not expanded, but remains as a reminder of past problems. These are exceptional cases.

Table 3. Percent of plot trees exhibiting MCY symptoms in Puruki-Tahi. The trees are widely spaced (60 trees/ha), with an understory of heavy bracken. Soil magnesium availability is suspected to be least in the northern part of Tahi, which has low Mg concentrations in stream water.

Part of catchment	MCY severity code A	B	C	D	Not scored
Northern	8	64	20	2	
Southern	54	38	8	0	
Overall	31	51	14	1	3

Radiata pine appears to be particularly sensitive

Species differences occur in uptake. *P. radiata* has lower uptake of Mg than adjacent *E. regnans* or *A. dealbata* (Frederick *et al.*, 1985) growing on similar sites. Furthermore, MCY symptoms are more severe in radiata than in other species growing on similar soils. Hence, genetic differences occur both within and between species.

Stag-head dates back to 1930's

This decline has important parallels with MCY from the description in Birch (1933):

- older trees > 13 years old
- volcanic soils of central North Island
- top of tree dies back, both leader and subsidiary leaders
- evident in dominant trees which become suppressed and die
- low needle density in tops of trees
- apparently not a fungus
- trees grow into the condition, limiting further development
- some soil or climatic factor thought to be involved
- not evident in other tree species present

If stag-head is simply another name for Mg deficiency- a tempting but untested hypothesis- then the work by Birch would indicate that MCY existed in "Old Crop" radiata at Kaingaroa, and is not a new phenomenon.

Magnesium deficiency - prognosis

Successive rotations can reduce readily available site nutrient reserves:

Stem only harvesting removes 66% of the Ca and Mg and 50% of the N and P, so drain on cations is proportionally greater (Webber and Madgwick 1983). Even with low impact harvesting technology (minimum soil compaction with delimbing and debarking at stump) large amounts of nutrients are removed during harvesting of the above ground tree components (Table 4).

Table 4. Amount of nutrients in above ground tree components of mature radiata stand in Kaingaroa Forest. The percentage removal data apply to a stem wood only harvesting operation. Current harvesting practices result in the additional removal or displacement of stem bark and tree crown matter, so the percentage removal figures are minimums.

Nutrient	Kg/ha contained in crop	% removal
N	434	34
P	66	36
K	464	42
Ca	333	52
Mg	102	51
Zn	5	47
Fe	9	57
Mn	29	63
S	54	39

Windrowing in Kaingaroa has been shown to reduce tree growth and, more particularly, Mg levels which decline markedly from 0.074 in normal sites to 0.058 in inter-windrow area (Ballard 1978). Of other nutrients examined (N, P, K, Ca, B), boron concentrations also declined significantly, with other nutrients affected to a lesser extent. Maintenance of nutritional status then depends on the rate of Mg supply from atmospheric deposition (negligible inland) and mineral weathering of Mg.

The total capital of Mg in southern Kaingaroa, where Mg symptoms are severe, is reported to average 13,000 kg/ha in the top 60cm of soil (Hunter *et al.*, 1986), indicating that ample Mg occurs in the soil for many rotations. Even with ample Mg in profile the soil supply rate can be too slow to meet requirements (Hunter *et al.*, 1986), unless fertiliser is applied. Mg deficiency symptoms occur in radiata because the rate of Mg supply is too slow.

Demands on site nutrient reserves are increasing

Tree improvement programmes aim to increase growth rates through choice of species (especially fast growing conifers) and through tree breeding, without directly considering nutritional requirements of improved breeds. Species comparisons on the same site (Frederick *et al.*, 1985) show that other species can take up more Mg than radiata.

Enhanced levels of atmospheric CO_2 are expected to increase productivity by approximately 20 percent within two rotations, while concomitantly decreasing stomatal conductivity and thereby transpiration rates. Will nutrient stress increase? Ambient CO_2 levels have already increased significantly and stands may be showing signs of stress where nutritional requirements are not being adequately met.

Demand for agricultural land suited to forestry use is increasing:

Afforestation of pastoral land is an attractive option because establishment costs are low, but these sites are likely to be inland hill soils which are marginal in terms of Mg nutrition. Expansion of forestry onto this marginal land will increase the need for preventative or remedial action.

Magnesium nutrition - *what should we be doing*?

Better monitoring

Upper tree crowns are physically difficult to sample in older trees, so emerging health problems may not be recognised until visual symptoms become apparent. As already indicated, remedial actions can then be rather ineffective because recovery from Mg deficiency symptoms following fertilisation can be slow. Prevention is therefore better than cure, requiring correct foliage sampling procedures and identification of susceptible sites

Improvement of tree nutritional traits - a viable option?

The use of genotypes which demonstrate a capacity to grow well in deficient soils warrants study. Genetic differences in nutrition are known to exist for a range of nutrients, including Mg (Knight 1978, Burdon 1976), and tree selection for breeding or cloning should favour these genotypes. Given the coastal distribution of native stands of radiata in the USA, and historical distribution on serpentine soils (Waring *pers comm.*) radiata has had little if any natural selection pressure to improve Mg uptake and use efficiency in its native range. Improving nutrient uptake through better design of root system (rooting density, distribution), and mycorrhizal associations are seen as promising avenues of research (Nambiar 1984).

Both magnesium and boron foliar levels tend to be marginal in NZ, and these nutrients are therefore candidates for inclusion in a tree improvement programme. The confounding effect owing to possible genotype-site interactions (Burdon 1976) suggests the need for caution: clonal differences in nutrient concentrations can change with soil type, suggesting the need for a regional approach.

Limited evidence suggests that foliar analysis can already be used to identify trees with differing nutrient uptake capability. More emphasis should be placed on obtaining individual tree foliar analysis information - both for seedling and clonal origin material - to separate the role of growth rate from allometric controls.

Tree improvement programmes, while continuing to improve disease resistance, and wood and log quality traits, could place less emphasis on growth rate *per se* and focus instead on tree stress and other health related traits, in order to better adapt the species to New Zealand's soils and management systems.

Graft incompatibility - parallel with MCY

Incompatibility (Mg deficiency type) symptoms are evident in Puruki grafts growing in nursery, ranking as follows: 448, 451, 454, 450 with the biggest contrast evident between 448 and the other 3 clones. Mg is implicated in graft incompatibility, and this symptom could signal a predisposition to MCY.

Other considerations

Environmental concerns influence forestry practices

Vegetation management research may wish to address the possible benefits of bio-diversity, additional to that derived from N fixation for example, as a means to improve nutrient cycling of trace elements. What species are particularly efficient at improving the Mg status of marginal sites by increasing Mg availability to radiata?

Nutrient leaching will be less if stands do not need to be fertilised. At Puruki Mg concentrations are highest in stream water draining stands showing the lowest incidence of MCY. Better matching of genotypes to the site capacity to supply nutrients would avoid the need to maintain higher soil solution Mg concentrations.

Recommendations

1) Classify nutritional characteristics of sites with respect to radiata pine average requirements - extending nutritional atlas. Refinements necessary include incorporating management inputs and practices in information systems (such as GIS), and gathering of more detailed soil information. Incorporate nutrient cycling models into GIS based planning systems, to serve as tools for predicting effects of age, silvicultural, harvesting intensity and site preparation practices on nutrient demand by the crop in relation to nutrient supply, should also be pursued.

2) Improve methods for routinely monitoring nutritional health of key research trials and managed stands. Photographic and video techniques coupled with GIS hold promise in this regard. Systematic foliar monitoring should be extended.

3) Determine systems for improving nutritional status of existing stands showing deficiency symptoms - currently part of cooperative programme. More basic work required on processes influencing uptake/translocation of nutrients (Mg).

4) Promote use of better adapted clones or breeds - currently part of government funded programme. More basic work is required to define traits of genotypes that are successful in Mg deficient areas, and to screen clones or breeds at an early age. The possibility of genotype-site interactions, and the heritability of nutritional traits also need to be examined.

5) Examine benefits of growing alternative species in mixture with radiata, or as an alternative to radiata.

Acknowledgements

The FRI working group included J. Aitken-Christie, P. Beets, R. Burdon, A. Coker, T. Payn, M. Skinner, A. Singh, A. Thorn, J. Zabkiewicz. Participants at the New Zealand Forest Nutrition Cooperative also provided valuable input during the field tour held on 10 February 1992.

References

Beets, P.N., Carson, S., Dick, M., Singh, A., Skinner, M., and Hunter, I. 1991: Mid-Crown Yellowing - on the increase. What's New in Forest Research No. 206.

Beets, P. N., and Pollock, D. S. 1987: Accumulation and partitioning of dry matter in *Pinus radiata* as related to stand age and thinning. New Zealand Journal of Forestry Science 17(2/3):246-71.

Burdon, R.D. 1976: Foliar macronutrient concentrations and foliage retention in radiata pine clones on four sites. New Zealand Journal of Forestry Science 5:250-9.

Ballard, R. 1978: Effect of slash and soil removal on the productivity of second rotation radiata pine on a pumice soil. New Zealand Journal of Forestry Science 8:248-58.

Birch T.C. 1933: Report on diseases of pines in the pumice country (Nov., 1932) and supplement (December, 1933). Unpublished.

Frederick, D.J., Madgwick, H.A.I., Jurgensen, M.F., and Oliver, G.R. 1985: Dry matter, energy, and nutrient contents of 8-year old stands of *Eucalyptus regnans*, *Acacia dealbata*, and *Pinus radiata* in New Zealand. New Zealand Journal of Forestry Science 15:142-57.

Hunter, I.R., Prince, J.M., Graham, J.D., and Nicholson, G.M. 1986: Growth and nutrition of *Pinus radiata* on rhyolytic tephra as affected by magnesium fertiliser. New Zealand Journal of Forestry Science 16:152-65.

Hunter, I.R., Rodgers, B.E., Dunningham, A., Prince, J.M., and Thorn, A.J. 1991: An atlas of radiata pine nutrition in New Zealand. FRI Bulletin No. 165.

Knight, P.J. 1978: Foliar concentrations of ten mineral nutrients in nine *Pinus radiata* clones during a 15-month period. New Zealand Journal of Forestry Science 8:351-68.

Madgwick, H. A. I.; Sims, A.; Oliver, G. R. 1988: Nutrient content and uptake of closed-spaced *Pinus radiata*. New Zealand Journal of Forestry Science 18:65-76.

Nambiar, E.K.S. 1984: Increasing forest productivity through genetic improvement of nutritional characteristics. pp 191-215 in Forest Potentials. Weyerhaeuser Co., Tacoma, WA.

Roberts, T.M., Skeffington, R.A., Blank, L.W. 1989: Causes of Type I Spruce decline in Europe. Forestry 62:179-222.

Webber, B.; Madgwick, H.A.I. 1983: Biomass and nutrient content of a 29-year-old Pinus radiata stand. New Zealand Journal of Forestry Science 13:222-8