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# **BORON DYNAMICS AND AVAILABILITY IN *PINUS RADIATA* PLANTATION**

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A thesis presented in partial fulfilment of the requirements  
for the degree of

**Doctor of Philosophy**

in

Soil Science



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New Zealand

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# Abstract

*Pinus radiata* is an important forest species in New Zealand. Over 89 % of the country's plantation forestry area is planted with *P. radiata*. The species makes a major contribution to New Zealand's \$3.1 billion to GDP and the plantation area is projected to increase to 2.5 million hectares by 2025. Research work to date has recognised that soil B deficiency is a major issue in many forestry plantation areas. Edaphic and environmental conditions such as the coarse texture pumacious soils planted with radiata in the Central North Island, and summer drought condition in some areas, further aggravate B deficiency in New Zealand soils.

Boron deficiencies in *P. radiata* lead to growth defects in afflicted plants and a deterioration in wood quality and market value. The primary objective of this thesis was to assess the impact of ulexite, a slow-release B fertiliser, on the bioavailability of soil B, plant B uptake, and the relative effect of B application rate on plant growth and soil microbial activity. A further objective was to compare the rate of B adsorption to seven benchmark soils collected from the North Island of New Zealand. The purpose of the work was to propose a long-term slow-release fertiliser management solution for radiata pine forestry that may mitigate the economic damage caused by B deficiency in this important primary production sector.

Soil was collected from Taupo, the major *P. radiata* planting district in the Central North Island of New Zealand, and used to establish glasshouse studies with *P. radiata* at Massey University in Palmerston North. Plants for this research were obtained from the Forest Research Institute (SCION) in Rotorua, New Zealand. Two growth experiments were conducted. The second of these compared the B dynamics of a fast-growing and slow-growing clone of *P. radiata*.

The background concentration of B in this soil (less than 0.5 mg/kg calcium chloride extractable B) is low, and B fertiliser application induced a soil response. Results showed that the concentration of plant-available B (extracted using hot 0.02 M CaCl<sub>2</sub>) significantly increased with B application. Boron application at the highest level (32 kg/ha) led to a build-up of soil B to a critical toxicity level with the subsequent appearance of toxicity symptoms in plants.

Application of B resulted in rapid B uptake as shown by an increase in B concentration in all plant parts (needle, stem and roots), but with the greatest rate of increase in needles. The percentage distribution of B throughout the plant showed that B distribution was influenced by B application treatments. The root to needle B ratio is used in this work as an index of B transfer from source to sink parts of a plant. Results showed that under deficient and toxic soil B concentrations (defined through the  $\text{CaCl}_2$  extractable B concentration), B was restricted to source tissues. However, B application at the rate of 4 kg/ha enabled B to move to sink parts including the new emerging needles. Regardless of clone and B treatment, needles, particularly older needles, were the main site of B accumulation followed by roots and stem. The B concentration in needles of Clone 37 was higher than in Clone 18 and this result reflects a higher demand of B for the faster growing Clone 37 relative to Clone 18.

Application of B affected *P. radiata* growth in terms of height, diameter and plant dry weight. Plants responded positively to B application over a range of fertiliser treatments (8-16 kg/ha) leading to sufficiency in soil as quantified through increases in the plant growth parameters plant height and dry weight. Boron application improved plant physiology as quantified by photosynthesis in this study. Results showed that photosynthesis positively responded to B application up to 8 kg/ha, however a further increase in B application resulted in a decline in photosynthetic activity.

Results from a B fractionation study showed that the plant unavailable residual-B fraction was the major form of B in the Taupo soil. With B fertiliser application the concentration of readily-available B increased proportionally to the B application rate. This increase in readily-available B demonstrates the importance of using B fertiliser to provide for a long-term increase in plant-available soil B for *P. radiata* plantations on the Taupo soil.

Soil microbial and microbiological properties also responded to B application. Soil dehydrogenase activity, an index of microbiological activity in soil, showed a concentration gradient from the bulk to rhizosphere soil. Regardless of clone there was approximately a three-fold higher dehydrogenase activity in the rhizosphere soil compared to the bulk soil. Maximum dehydrogenase activity was recorded by a B application at 4-8 kg/ha in both clones with a decrease in activity at higher rates.

Regardless of the radiata clone used, mycorrhizal colonisation increased with B application. However, for both clones the maximum mycorrhizal infection on roots was recorded for a B application rate of 2-4 kg/ha.

A B adsorption study performed using seven benchmark soils collected from around the North Island showed that B adsorption increased in all soils with the concentration of B in equilibrium solution. Langmuir and Freundlich isotherms modelled B adsorption in all seven soils. Further studies showed that B adsorption corresponded to pH in solution and linearly increased up to pH 9 and reduced thereafter.

The results from this study demonstrate the importance of B fertiliser to *P. radiata* plantation forestry. Both plant and microbiological parameters are affected by both low and excess levels of soil B. Therefore, it is suggested that a B application rate in the range of 4-8 kg/ha is optimal for plant growth and will have no harmful effect on soil microbiological parameters. In contrast, B application at the rate of 16 kg/ha is toxic to both plants and soil microbes and will lead to inhibitory effects on activity and growth.

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**Raza Ullah Khan**

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# **Dedication**

I dedicate this thesis to my late Great Grandmother

# TABLE OF CONTENTS

Abstract .....	i
Acknowledgements.....	iv
Table of contents.....	vii
List of Figures, Tables and Equations .....	xiii
<b>Chapter 1 Background and Research Objectives.....</b>	<b>1</b>
1.1 Background.....	1
1.2 Use of B fertilisers in <i>Pinus radiata</i> .....	3
1.3 Objectives of the research study .....	4
<b>Chapter 2 Review of Literature .....</b>	<b>6</b>
2.1 Introduction: An overview .....	6
2.2 Aqueous chemistry of B .....	7
2.3 The occurrence of B on earth.....	8
2.4 Soil factors affecting B availability .....	11
2.4.1 pH .....	13
2.4.2 Parent material	14
2.4.3 Liming	14
2.4.4 Soil texture and clay minerals	16
2.4.5 Soil organic matter	17
2.4.6 Soil water content	19
2.4.7 Soil salinity	20
2.4.8 Summary: Boron adsorption and fixation in Soil.....	20
2.5 Environmental factors.....	21
2.5.1 Sun light intensity	21
2.5.2 Rainfall and moisture	22
2.5.3 Temperature, humidity and transpiration rate	22
2.5.4 Distance from sea and sea spray	23
2.6 Sources of B.....	24

2.6.1	Anthropogenic sources of soil B	24
2.6.2	Boron fertiliser	24
2.6.3	Irrigation water	26
2.6.4	Leaching	28
2.6.5	Municipal compost, biosolids and industrial effluents.....	29
2.6.6	Coal fly ash	30
2.7	Boron in soils: total vs. bioavailable concentration .....	30
2.7.1	The total soil boron (TSB) status of soil	30
2.7.2	Bioavailable or Plant-available Boron	31
2.7.2.1	Hot water extractable B (HWEB)	33
2.7.2.2	Hot CaCl <sub>2</sub> extractable B	34
2.7.3	The effect of depth on the water extractable B concentration of soil	36
2.8	Analytical techniques for B determination in solution .....	36
2.8.1	Interpretation of soil B level .....	37
2.9	Soil dehydrogenase activity and B.....	38
2.10	Boron fractionation .....	39
2.10.1	Exchangeable or readily-soluble B (solution plus non- specifically sorbed)	40
2.10.2	Specifically-sorbed B	42
2.10.3	Iron and manganese oxides-bound B	42
2.10.4	Organically-bound B	42
2.10.5	Residual	43
2.11	Boron interaction and availability influenced by other elements .....	43
2.11.1	Interaction in Soil.....	43
2.12	Importance of forestry in New Zealand .....	44
2.13	Boron cycling in Pinus radiata forest ecosystem .....	45
2.14	Boron nutrition of forest trees.....	47
2.14.1	Boron functions in plants	47

2.14.2	The effect of boron on wood quality	48
2.14.3	Boron uptake and plant requirements	48
2.15	Boron deficiency .....	50
2.15.1	Symptoms of B deficiency	50
2.15.2	Boron fertiliser effect on tree growth	52
2.16	Boron and rhizosphere effect .....	55
2.17	Boron role in Mycorrhizae .....	56
2.18	Boron role in photosynthesis .....	57
2.19	Boron Interaction with other nutrients in Plants .....	57
2.20	Boron deficiency and toxicity across the globe .....	59
2.20.1	Global deficiency trends	59
2.20.2	Global toxicity trends	60
2.21	Structure of thesis .....	65
<b>Chapter 3 Response of Pinus radiata to slow release boron</b>		
	<b>fertiliser .....</b>	<b>69</b>
3.1	Introduction.....	69
3.2	Materials and Methods.....	70
3.2.1	Experiment design and plant growth conditions .....	70
3.3	Measurement and chemical analysis.....	73
3.3.1	Needle net photosynthesis rate, plant growth and dry weight.....	73
3.3.2	Soil sampling and preparation	74
3.3.3	Analysis of soil boron	75
3.3.4	Boron fractionation using a sequential extraction procedure.....	75
3.3.4.1	Readily soluble B .....	74
3.3.4.2	Specifically adsorbed B .....	74
3.3.4.3	Oxide bound B .....	74
3.3.4.4	Organically bound B .....	74
3.3.4.5	Residual B .....	75
3.3.5	Soil dehydrogenase activity	78

3.3.6	Mycorrhizae Scoring	78
3.3.7	Plant Boron	79
3.4	Data analysis .....	80
3.5	Results and Discussion .....	80
3.5.1	Plant growth, dry weight, and net photosynthesis rate.....	80
3.5.2	Plant B concentration and percentage B distribution in plant organs	83
3.5.3	Plant available soil B and soil dehydrogenase activities.....	86
3.5.4	Relationship between the CaCl <sub>2</sub> extractable soil B and the plant B concentration	88
3.5.5	Boron fractionation in soil .....	90
3.5.6	Mycorrhizal colonization in <i>Pinus radiata</i> .....	92
3.6	Conclusions .....	91
Chapter Four Comparative responses of two clones of <i>Pinus radiata</i> to boron fertiliser .....		
		96
4.1	Introduction.....	96
4.2	Materials and methods .....	97
4.2.1	Experimental design and plant growth conditions .....	97
4.2.2	Measurement and chemical analysis	99
4.2.2.1	Plant growth, total fresh and dry weights	.99
4.2.2.2	Photosynthesis measurement .....	97
4.2.2.3	Soil sampling and preparation .....	101
4.2.2.4	Soil boron analysis.....	101
4.2.2.5	Soil dehydrogenase activity determination.....	102
4.2.2.6	Mycorrhizal colonisation assessment.....	99
4.2.2.7	Plant boron analysis .....	100

4.2.3	Quality control parameters.....	103
4.2.4	Data analysis.....	104
4.3	Results and discussion .....	104
4.3.1	Plant growth.....	104
4.3.2	Net photosynthetic rate, stomata conductance and light response curve.....	113
4.3.3	Boron concentration and distribution in plant organs .....	118
4.3.3.1	Plant B concentrations .....	115
4.3.3.2	Percentage B distribution .....	120
4.3.4	The distribution of B in soil.....	125
4.3.4.1	Boron fractions .....	121
4.3.4.2	Plant available soil B .....	123
4.3.5	Soil dehydrogenase activity and mycorrhizal colonisation.....	131
4.3.5.1	Soil dehydrogenase activity .....	127
4.4	Conclusions.....	136
	<b>Chapter Five Boron adsorption in soils .....</b>	<b>138</b>
5.1	Introduction.....	139
5.1.1	Boron adsorption on clay minerals	140
5.1.2	Boron adsorption on organic matter	142
5.1.3	Modelling boron adsorption	144
5.1.4	Study objectives	146
5.2	Materials and methods .....	146
5.2.1	Chemical analysis	146
5.2.2	Particle size distribution	150
5.2.3	Boron adsorption batch study	150

5.2.4	Boron adsorption at varying pH	152
5.3	Data analysis .....	152
5.4	Results and Discussion .....	153
5.4.1	Soil chemical and physical properties	153
5.4.2	Correlation between soil properties	155
5.4.3	Adsorption isotherms .....	150
5.4.4	Adsorption isotherms model: Langumir vs. Freundlich.....	159
5.4.4.1	The Langmuir adsorption model .....	153
5.4.4.2	The Freundlich adsorption model .....	159
5.4.5	Correlation study	169
5.4.6	The influence of pH on B adsorption	169
5.4.7	Conclusions	172
 <b>Chapter Six Overall conclusions and recommendations for future</b>		
	<b>research work .....</b>	<b>173</b>
6.1	Review of the current study .....	173
6.2	Objectives of the study .....	174
6.3	General discussion and conclusions .....	175
6.3.1	The availability of B to clones and the subsequent distribution of B within the clones	176
6.3.2	The effect of variable B fertiliser rates on soil microbes with particular focus on ectomycorrhizae	179
6.3.3	Response of plant photosynthesis to variable B fertiliser rates	179
6.3.4	Summary for the optimal level of B fertilisation for both plant and soil microbes species	180
6.4	Recommendations for future research work .....	182

# List of Figures, Tables and Equations

Figure 1.1	Major areas of boron deficiency in New Zealand after Will (1985)	2
	$B(OH)_3 + 2H_2O \leftrightarrow B(OH)_4^- + H_3O^+$ pKa 9.25 Equation (2.1)	7
Figure 2.1	Schematic diagram of B turnover in the environment after Kot (2009)	9
Table 2. 1	Soil properties affecting B availability in soil	12
Figure 2.2	Ca-metaborates	14
	The main reaction (Equation 2.2) occurring through the application of lime to acid soil, involves the replacement of exchangeable Al and hydroxyl-Al cation by calcium on soil colloid surfaces leading to the precipitation of $Al(OH)_3$ (Hatcher et al., 1967).	15
	$2AlX_3 + 3CaCO_3 + 3H_2O = CaX_2 + 2Al(OH)_3 + 3CO_2$ Equation (2.2)	15
Table 2. 2	Boron concentration (mg/kg) in major rock types after Shorrocks (1997)	16
Figure 2.3	Formation of a B-diol complex after Huettl (1976)	18
Table 2.3	Boron compounds, used as fertiliser after Mortvedt and Woodruff (1993)	26
Table 2. 4	Classification of irrigation water based on the tolerance of plant species to the B concentration in solution	28
Table 2. 5	Extraction techniques used to assess plant available B in soil after Nable et al. (1997)	32
Table 2.6	Optimum hot-water extractable B levels in soil for the growth of various crop species after Berger (1949)	34
Table 2. 7	Total, hot water and 0.02 M $CaCl_2$ extractable B in Canterbury after Adams et al. (1991)	35

Table 2. 8	Critical B concentration in soil for different crops and vegetables using hot water extractable B after Bell (1999) .....	38
Figure 2.4	Boron partition in <i>P. radiata</i> after Madgwick et al. (1988) .....	46
Figure 2.5	Leader dieback .....	51
Figure 2.6	Sever dieback affecting whole plant .....	51
Figure 2.7	Shoot and tip dieback .....	51
Table 2. 10	Trials on <i>P. radiata</i> using different sources and rates of B fertiliser .....	53
Table 2. 11	Reported soil boron deficiency across the main FAO/UNESCO soil groups of the world after Shorrocks (1997) .....	61
Table 2. 12	Deficient, sufficient, and toxic levels of B in a variety of plants after Gupta (1993b) .....	64
Table 2.13	Chapter structure of thesis .....	65
Table 3. 1	Chemical composition of ulexite .....	71
Table 3. 2	Climatic conditions and selected properties of Taupo soil used in this study .....	72
Table 3. 3	Description of codes used for needle and stem analysis .....	74
Figure 3.1	Schematic chart of the modified sequential extraction scheme adopted for this study after Datta al. (2002) .....	76
Table 3. 4	Effect of B application rates on plant height, stem diameter, dry weight, shoot root biomass weight and net photosynthesis .....	82
Figure 3.2	Yellowing tips at high B dose (32 kgB/ha) in <i>P. radiata</i> needles .....	83
Table 3.5	Effect of B application rates on B concentration in plant components (needle, stem and root) .....	84
Figure 3.3	Effect of B application on the percentage B distribution in plant parts .....	86
Table 3. 6	Effect of B application rates on CaCl <sub>2</sub> ext. soil B and Soil dehydrogenase activities .....	87

Figure 3.4	Relationship between hot CaCl <sub>2</sub> extractable soil B concentration and the B concentration in 1-year old needles .....	88
Figure 3.5	Relationship between hot CaCl <sub>2</sub> extractable soil B concentration and the B concentration in currently mature-needles .....	89
Figure 3.6	Relationship between hot CaCl <sub>2</sub> extractable soil B concentration and the B concentration in current-immature needles .....	89
Figure 3.7	Relationship between sum of all B fractions concentration and the total metal concentration determined by aqua regia digestion .....	90
Figure 3.8	Percentage distributions of B fractions in soil after B fertiliser application .....	92
Figure 3.9	Mycorrhizae hyphae counts of <i>P. radiata</i> roots as affected by the B fertiliser application rates. Bars with different letters shows significant difference at $p \leq 0.05$ .....	93
Figure 4.1	Schematic diagram showing the placement of ulexite at different soil depths in each experimental pot .....	98
Figure 4.2	Layout of the pot trial in glasshouse .....	99
Table 4.1	Description of codes used for needle and stem sampling and analysis .....	100
Table 4.2 a	<i>P</i> values for main and interactive treatment effects for plant height stem basal diameter, fresh and dry weights of radiata pine at harvest .....	105
Table 4.2 b	<i>P</i> values for main and interactive treatment effects for dry weights of plant parts and the shoot to root dry weight ratio of radiata pine at harvest	105
Figure 4.3	Plant height responses of two radiata pine clones to different rates of B fertiliser. Means for each clone with different letters are significantly different ( $p < 0.05$ ) .....	106
Figure 4.4	Stem diameter response of two radiata pine clones to different rates of B fertiliser .....	107
Figure 4.5	Total fresh weight response of two radiata pine clones to different rates of B fertiliser. Means for each clone with different letters are significantly different ( $p < 0.05$ ) .....	108

Figure 4.6	Total dry weight response of two radiata pine clones to different rates of B fertiliser. Means for each clone with different letters are significantly different ( $p < 0.05$ ) .....	109
Table 4.3	Effect of boron (B) rate and clone on the dry weight recorded for different age classes of needles and stems .....	110
Figure 4.7	Stem dry weight response of two radiata pine clones to different rates of B fertiliser. Means for each clone with different letters are significantly different ( $p < 0.05$ ) .....	111
Figure 4.8	Root dry weight responses of two radiata clones to different rates of B fertiliser .....	112
Figure 4.9	Shoot root dry weight ratio response of two radiata clones to different rates of B fertiliser. Means for each clone with different letters are significantly different ( $p < 0.05$ ) .....	113
Table 4.4	<i>P</i> values for main and interactive treatment effects on net photosynthetic rate of current-year needle and stomata conductance of radiata pine measured before harvest .....	114
Figure 4.10	Effect of B application rates on net photosynthetic rate in current year needles ( $P_n$ ) of Clone 18 and 37. Means for each clone with different letters are significantly different ( $p < 0.05$ ) .....	115
Figure 4.11	Effect of B application rates on stomata conductance of Clone 18 and 37. Means for each clone with different letters are significantly different ( $p < 0.05$ ) .....	115
Figure 4.12	Photosynthetic light response curves of Clone 18 and 37, as affected by B application rates .....	117
Table 4.5	<i>P</i> values for main and interactive treatment effects on needle, stem and root B concentrations ( $< 0.05$ shown bold) .....	119
Figure 4.13	Boron concentrations in one year-old (NI), currently mature (NCM), and currently immature (NCI) needles of Clone 18 (A) and Clone 37 (B). Means for each clone with different letters are significantly different ( $p < 0.05$ ) .....	121

Figure 4.14	Stem B concentrations in one year-old stem (SI), and current-year stem (SC) in Cone 18 (A) and Clone 37 (B). Means for each clone with different letters are significantly different ( $p < 0.05$ ) .....122
Figure 4.15	Root B concentrations of Clone 18 and 37, as affected by B application rates. Means for each clone with different letters are significantly different ( $p < 0.05$ ) .....123
Figure 4.16	Percentage B distribution in plant parts of two <i>P. radiata</i> clones, as affected by B application rates .....125
Figure 4.17	Percentage distribution of B within each of five defined B fractions in soil as a function of B treatment rate .....126
Figure 4.18	Relationship between the sum of five B fractions and total soil B by single digestion at harvest time for (A) Clone 18 and (B) Clone 37 .....127
Table 4.6	<i>P</i> values for main and interactive treatment effects on the plant available soil B concentration extracted from different soil depths .....129
Figure 4.19	CaCl <sub>2</sub> -extractable B concentration in soil at the time of harvesting Clone 18 and Clone 37. Means for each clone with different letters are significantly different ( $p < 0.05$ ) .....129
Figure 4.20	CaCl <sub>2</sub> -extractable B concentration in soil under Clone 18 at two sampling depths (0-10 and 10-20 cm) at the time of harvest. Means for each depth with different letters are significantly different ( $p < 0.05$ ) .....130
Figure 4.21	CaCl <sub>2</sub> -extractable B concentration in soil under Clone 37 at two sampling depths (0-10 and 10-20 cm) at the time of harvest. Means for each depth with different letters are significantly different ( $p < 0.05$ ) .....130
Table 4.7	<i>P</i> values for main and interactive treatment effects on soil dehydrogenase activities both in rhizosphere and non-rhizosphere soils, and on mycorrhizal colonisation .....131
Figure 4.22	Soil dehydrogenase activities (TPF) in bulk and rhizosphere soils of Clone 18, as affected by different rates of B fertiliser. Means for each soil with different letters are significantly different ( $p < 0.05$ ) .....132

Figure 4.23	Soil dehydrogenase activities (TPF) in bulk and rhizosphere soils of Clone 37, as affected by different rates of B fertiliser. Means for each soil with different letters are significantly different ( $p < 0.05$ ) .....	134
Figure 4.24	Mycorrhizae hyphae count of two <i>P. radiata</i> Clones in response to different B application rates. Means for each clone with different letters are significantly different ( $p < 0.05$ ) .....	135
Table 5. 1	Four types of adsorption isotherm described by Sposito (1984) for soil .....	140
Table 5.2	Description of the soil used in this study after Hewitt (1998) .....	148
Table 5.3	Physical and Chemical properties of soils from Jeyakumar (2010) .....	154
Table 5.4	Simple linear correlation coefficients between soil properties .....	155
Figure 5.1	Relationship between B in equilibrium solution and B adsorbed on (A) Recent Soil (B) Ultic Red Soil (C) Pallic Soil and (D) Gley Soil .....	157
Figure 5.2	Relationship between B in equilibrium solution and B adsorbed on (A) Brown Soil (B) Allophanic Soil (C) Pumice Soil .....	158
Figure 5.3	Schematic transformation of an adsorption isotherm from a non-linear (red) portion to a linear (blue) portion as the equilibrium B concentration increases .....	159
Table 5.5	Boron adsorption parameters of the fitted Langmuir isotherms .....	161
Figure 5.4	Langmuir isotherms for B sorption onto (A) Recent Soil (B) Ultic Red Soil (C) Pallic Soil and (D) Gley Soil .....	162
Figure 5.5	Langmuir isotherms for B sorption onto (A) Brown Soil (B) Allophanic Soil (C) Pumic Soil .....	163
Table 5.6	Boron adsorption reported in literature from studies around the world compared with that for the current study .....	164
Figure 5.6	Freundlich isotherms for B sorption onto (A) Recent Soil (B) Ultic red Soil (C) Pallic Soil and (D) Gley Soil .....	166
Figure 5.7	Freundlich isotherms for B sorption onto (A) Brown Soil (B) Allophanic Soil and (C) Pumic Soil .....	167

Table 5.7	Boron adsorption parameters of Freundlich isotherms <sup>Δ</sup> .....	168
Table 5.8	Correlation coefficient (r) for comparison of each adsorption isotherm parameter and soil properties .....	169
Figure 5.8	Boron adsorption as a function of solution pH .....	170
Figure 5.9	Relative distributions of B species with changing pH .....	171
Table 6.1	Effect of soil B on plant deficiency and toxicity symptoms .....	177
Table 6.2	Optimum B level for plant and microbes under glasshouse conditions .....	181
Table 6.3	Adsorption maximum observed in range of soils .....	181
Figure 6.1	Schematic model for B cycling in <i>Pinus radiata</i> forestry.....	183