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**Investigation on the effect of biochar  
addition and the use of pasture species  
with different rooting systems on soil  
fertility and carbon storage**

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

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## Abstract

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There is a potential to increase soil carbon (C) sequestration in New Zealand pastoral soils, especially in the subsoils where the soil C stocks have been reported to have a greater C saturation deficit than the topsoils. Selecting pasture species with deeper root systems will enhance soil formation at depth and mineral weathering, thus enhancing the potential for soils to stabilize organic matter (OM). Moreover, the addition of biochar may increase the stable C pool of soils and provide other additional benefits. Up to the present time few studies have investigated the potential of biochar to promote root growth and allocation of plant C to the subsoil. A glasshouse study was carried out to examine the effect of adding a nutrient-rich biochar at various dose (0, 1.5, 5 and 10 Mg ha<sup>-1</sup> without nitrogen (N) fertiliser; 0, 1.5, 10 and 20 Mg ha<sup>-1</sup> with N fertiliser at a dose of 113 kg N ha<sup>-1</sup>) to a sandy soil on plant growth (above- and below-ground). The results indicated that, in the absence of N limiting conditions, biosolids-derived biochar could improve plant biomass yield as a result of the addition of available P and K. This amendment also caused an increase in plant root length. Subsequently, a 2-year lysimeter trial was set up to compare changes in C stocks of soils under deep- or shallow-growing pastures as well as to investigate whether biochar addition below the top 10 cm could promote root growth at depth. For this: i) soil ploughing at cultivation for pasture establishment was simulated in two different soils (a silt loam soil and a sandy soil) by inverting the 0–10 and 10–20 cm depth soil layers, and biochar was mixed at a rate of 10 Mg ha<sup>-1</sup> in the buried soil layer, where appropriate; and ii) three pasture types with contrasting root systems were grown. Distinctive biochars were selected for these two soils so that soil-specific plant growth limitations could be overcome. In the silt loam, soil inversion resulted in a net loss of native organic C in the buried horizon under shallow-rooted species, but not under deep-rooted species. The addition of a C-rich pine biochar (equivalent to 7.6 Mg C ha<sup>-1</sup>) to this soil resulted in a net C gain (6–16% over the non-biochar treatment, calculated up to 30 cm;  $P < 0.05$ ) in the buried soil layer under all pasture treatments; this overcame the net loss of native organic C in this horizon under shallow-rooted pastures. In the sandy soil all pasture species were able to maintain soil C stocks at 10–20 cm depth over time. In this soil, the exposure of a skeletal and nutrient-depleted soil layer at the surface may have fostered root growth at depth. The addition of a nutrient-rich biosolids biochar (equivalent to 3.6 Mg C ha<sup>-1</sup>) to this soil had no apparent effect on total C stocks. In this 2-year study, none of the biochar amendments affected either pasture yield or root growth. More research is needed to understand the mechanisms through which soil C stocks at depth are preserved.

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## Table of Contents

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Abstract .....	i
Acknowledgements.....	ii
Table of Content .....	iii
List of Figure .....	vi
List of Table.....	viii
List of Picture .....	viii
<b>Chapter 1. Introduction</b> .....	1
1.1. Overall importance of the research.....	1
1.2. Objectives of the research .....	4
1.3. Outline of the thesis with the hypotheses and objectives .....	5
References .....	6
<b>Chapter 2. Literature Review</b> .....	11
2.1. Soil Organic Matter.....	11
2.1.1. Soil OM stabilisation in soil.....	11
2.1.2. Soil C saturation .....	18
2.2. Deep Soil Organic Matter: Potential for Storing C in the Subsoil .....	19
2.2.1. Dynamic of subsoil OM.....	20
2.2.2. Influence of root chemical composition on SOM stabilisation of root-derived C .....	21
2.2.3. Soil management practices to increase subsoil C.....	23
2.3. Biochar.....	24
2.3.1. Biochar production system.....	24
2.3.2. Biochar C Stability.....	25
2.3.3. The availability of nutrients from biochar .....	28
2.4. Biochar and root interaction .....	31
2.5. Conclusion and research gap identified in the literature review .....	31
References .....	32
<b>Chapter 3. The Application of Biochar Made from Biosolids to Increase The Fertility of A Sandy Soil: A Glasshouse Study</b> .....	41
3.1. Introduction.....	41
3.2. Material and Methods .....	42
3.2.1. Production of biochars .....	42
3.2.2. Characterisation of biochars.....	43
3.2.3. Soil collection .....	45
3.2.4. Glasshouse experiment .....	45

3.2.5.	Root length measurements .....	46
3.2.6.	Plant and leachate analysis.....	46
3.2.7.	Statistical analysis.....	46
3.3.	Results .....	47
3.3.1.	Materials used for feedstocks and biochar characteristics .....	47
3.3.2.	Above-ground biomass.....	49
3.3.3.	Root length measurement.....	50
3.3.4.	Nutrients in above-ground biomass .....	51
3.3.5.	Nitrogen in leachates .....	54
3.4.	Discussion .....	55
3.4.1.	Biochar properties.....	55
3.4.2.	Above-ground biomass production .....	56
3.4.3.	Biochar and C sinks.....	59
3.5.	Conclusions.....	60
	Acknowledgement .....	60
	References .....	61
	<b>Chapter 4. Biochar Lysimeter Trial: 1. Description of The Setting of Lysimeter Trial and Above- and Below- Ground Plant Biomass Production Over The 2-Years Experiment .....</b>	<b>65</b>
4.1.	Introduction.....	65
4.2.	Materials and Methods.....	67
4.2.1.	Feedstock and Biochar Production .....	67
4.2.2.	Biochar Characterisation .....	68
4.2.3.	The Establishment of Lysimeter Trial with biochar application .....	70
4.2.4.	Plant Development and Monitoring .....	74
4.2.5.	Above Ground and Bellow Ground Biomass Sampling.....	75
4.2.6.	Statistical Analysis .....	77
4.3.	Results .....	77
4.3.1.	Biochar Properties.....	77
4.3.2.	Above-ground Biomass Production .....	78
4.3.3.	Live and dead root biomass.....	82
4.4.	Discussion .....	85
4.4.1.	Pasture DM production .....	85
4.4.2.	Biochar influence on the total DM production.....	87
4.4.3.	Live and dead root biomass.....	89
4.5.	Conclusion .....	91
	References .....	92

<b>Chapter 5. Biochar Lysimeter Trial: 2. Changes in Soil C and N Stocks Over The 2-Years Experiment ...</b>	<b>98</b>
5.1. Introduction .....	98
5.2. Material and Methods .....	100
5.2.1. Lysimeter Trial .....	100
5.2.2. Soil Sampling and C-N Analysis .....	100
5.2.3. Calculation on the cumulative soil C and N stock.....	100
5.2.4. Statistical Analysis .....	101
5.3. Results .....	101
5.3.1. Soil C and N content .....	101
5.3.2. Assessment of soil C and N stocks .....	105
5.4. Discussion .....	108
5.4.1. TK soil under different pastures with and without PI-350 biochar amendment (experiment 1) .....	108
5.4.2. MS soil under different pastures with and without BG-550 biochar amendment (experiment 2) .....	110
5.5. Conclusion .....	111
References .....	112
<b>Chapter 6. General conclusion and recommendation.....</b>	<b>116</b>
6.1. Overall Summary and general conclusions.....	116
6.1.1. Ryegrass response to the addition of high ash-nutrient rich biochar in the top 10 cm of soil depth.....	116
6.1.2. Pasture response and soil C change following the addition of C-rich biochar in the subsoil of a silt loam soil (lysimeter experiment 1) .....	117
6.1.3. Pasture response and soil C change following the addition of high ash nutrient-rich biochar in the subsoil of a coarse sandy soil (lysimeter experiment 2).....	118
6.2. Recommendation for future research.....	118
<b>Appendices.....</b>	<b>120</b>
Appendix 1. Raw data of the preliminary glasshouse experiment (Chapter 3) .....	120
Appendix 2. Data of lysimeter trial experiment 1 (Pastures on loamy Tokomaru soil with and without the application of PI-350 biochar) (Chapter 4 and Chapter 5) .....	123
Appendix 3. Data of lysimeter trial experiment 2 (Pastures on sandy Motuiti soil with and without the application of BG-550 biochar) (Chapter 4 and Chapter 5).....	126
Appendix 4. Methods to calculate soil Total Carbon (TC) and Total Nitrogen (TN) stocks (Chapter 5)...	129



## List of Figures

Figure 2.1. Mean Residence Time of Molecular Organic Structure.....	12
Figure 2.2. The zonal model of organo-mineral interactions.....	16
Figure 2.3. Relationship between input level of C and SOC at steady state.....	17
Figure 2.4. Various stabilisation mechanisms of C from roots.....	21
Figure 3.1 FTIR spectra of the biochar made from biosolids (BS), and the biochar made from a 1:1 (mass basis) mixture of biosolids and greenwaste.....	48
Figure 3.2. Above-ground biomass yield (g DM pot <sup>-1</sup> ) of ryegrass grown on pots of Waitarere soil fertilized with 0 and 113 kg N ha <sup>-1</sup> (N1 and N0, respectively) and different rates and types of biochar (biosolids biochar, BS; biosolids-green waste biochar, BG). Data represent the average and the standard error of the mean (SEM) (n = 3).....	49
Figure 3.3. Root length (cm cm <sup>-3</sup> ; in the top 12 cm) of ryegrass grown on pots of Waitarere soil fertilized with 0 and 113 kg N ha <sup>-1</sup> (N1 and N0, respectively) and different rates and types of biochar (biosolids biochar, BS; biosolids-greenwaste biochar, BG). Data represent the average and the standard error of the mean (SEM) (n = 3).....	50
Figure 3.4. Nitrogen and P concentrations and total amounts in above-ground biomass of ryegrass grown on pots of Waitarere soil fertilised with 0 and 113 kg N ha <sup>-1</sup> (N1 and N0, respectively) and different rates and types of biochar (biosolids biochar, BS; biosolids-green waste biochar, BG). Data represent average and the residual mean square error (RMSE) (n = 3).....	51
Figure 3.5. Potassium and Ca concentrations and total amounts in above-ground biomass of ryegrass grown on pots of Waitarere soil fertilised with 0 and 113 kg N ha <sup>-1</sup> (N1 and N0, respectively) and different rates and types of biochar (biosolids biochar, BS; biosolids-green waste biochar, BG) Data represent average and the residual mean square error (RMSE) (n = 3).....	52
Figure 4.1. Drainage collection column used in the experiment.....	71
Figure 4.2 Monthly global radiation, average soil temperature, and cumulative monthly rainfall during the 2 years of trial. The events of fertilizer addition to soil and plant “harvest” also indicated.....	75
Figure 4.3 Schematic figures of soil sampling.....	77
Figure 4.4 Cumulative above-ground biomass productions of different pasture plants on Tokomaru soil.....	79
Figure 4.5 Cumulative above-ground biomass productions of different pasture plants on Motuiti soil..	81
Figure 4.6 Live and dead roots biomass distribution (mg cm <sup>-3</sup> ) with depth after biochar addition and growth of different pasture species in lysimeter containing Tokomaru silt loam soil (experiment 1): a) ryegrass; b) red-clover and cocksfoot mixture; c) chicory. Data represent the average and the standard error of the means (SEM) (n=4) (For each depth, bars with different letters indicate significant differences at <i>P</i> < 0.05 between control and biochar amended soil; shaded area represent the depth of biochar application).....	83
Figure 4.7. Live and dead roots biomass distribution (mg cm <sup>-3</sup> ) with depth after biochar addition and growth of different pasture species in lysimeter containing Motuiti sandy soil (experiment 2): a) ryegrass; b) red-clover and cocksfoot mixture; c) lucerne. Data represent the average and the standard error of the means (SEM) (n=4) (For each depth, bars with different letters indicate significant differences at <i>P</i> < 0.05 between control and biochar amended soil; shaded area represent the depth of biochar application).....	84
Figure 5.1 Changes in soil TC concentration (g kg <sup>-1</sup> ) with depth after biochar addition and growth of different pasture species in lysimeters containing Tokomaru silt loam soil (experiment 1): a) ryegrass; b) red colver-cocksfoot mixture; and c) chicory. Data represent the average and the standard error the means (SEM) (n = 4) (For each depth, bars with different letters indicate significant differences at <i>P</i> < 0.05 between control and biochar amended soil; shaded area represent the depth of biochar application) vertical dashed line represent the TC concentration at T0.....	102

Figure 5.2 Changes in soil TN concentration ( $\text{g kg}^{-1}$ ) with depth after biochar addition and growth of different pasture species in lysimeters containing Tokomaru silt loam soil (experiment 1): a) ryegrass; b) red colver-cocksfoot mixture; and c) chicory. Data represent the average and the standard error the means (SEM) ( $n = 4$ ) (For each depth, bars with different letters indicate significant differences at  $P < 0.05$  between control and biochar amended soil; shaded area represent the depth of biochar application) vertical dashed line represent the TN concentration at T0..... 103

Figure 5.3 Changes in soil TC concentration ( $\text{g kg}^{-1}$ ) with depth after biochar addition and growth of different pasture species in lysimeters containing Motuiti sandy soil (experiment 2): a) ryegrass; b) cocksfoot and red clover mixture; and c) lucerne. Data represent the average and the Standard error the means (SEM) ( $n = 4$ ) (For each depth, bars with different letters indicate significant differences at  $P < 0.05$  between Control and biochar amended soil; shaded area represent the depth of biochar application) vertical dashed line represent the TC concentration at T0..... 104

Figure 5.4 Changes in soil TN concentration ( $\text{g kg}^{-1}$ ) with depth after biochar addition and growth of different pasture species in lysimeters containing Motuiti sandy soil (experiment 1): a) ryegrass; b) cocksfoot and red clover mixture; and c) lucerne. Data represent the average and the standard error the means (SEM) ( $n = 4$ ) (For each depth, bars with different letters indicate significant differences at  $P < 0.05$  between Control and biochar amended soil; shaded area represent the depth of biochar application) vertical dashed line represent the TN concentration at T0..... 104

Figure 5.5 Net gain and losses of TC and TN stocks in the biochar-amended treatments compared to the unamended ones [ $\Delta \text{TC}$  and  $\Delta \text{TN}$ : ( $\text{stocks}_{\text{control}} - \text{stocks}_{\text{biochar-amended}}$ ), in percentage] after 2 years of pasture establishment in the TK soil: a) ryegrass, b) cocksfoot and red clover mixture, c) chicory. *value followed by \* showed a significant difference at  $P < 0.05$* ..... 107

Figure 5.6 Net gain and losses of TC and TN stocks in the biochar-amended treatments compared to the unamended ones [ $\Delta \text{TC}$  and  $\Delta \text{TN}$ : ( $\text{stocks}_{\text{control}} - \text{stocks}_{\text{biochar-amended}}$ ), in percentage] after 2 years of pasture establishment in the MS soil: a) ryegrass, b) cocksfoot and red clover mixture, c) lucerne. *value followed by \* showed a significant difference at  $P < 0.05$*  ..... 108

## List of Tables

Table 2.1. Pyrolysis methods and characteristic of product generated from pyrolysis.....	24
Table 2.2. Nutrient properties of selected biochar from various type feedstocks.....	28
Table 3.1. Chemical characteristics of the materials used to produce the feedstocks.....	43
Table 3.2. Chemical characteristic of the soil used in the experiment.....	45
Table 3.3. Characteristics of biochar made from biosolids (BS) and from a 1:1 (dry weight basis) mixture of biosolids and green waste (BG).....	47
Table 3.4. Nitrate-N and ammonium-N concentrations in leachates from plant studies .....	54
Table 4.1. Soil Chemical Properties used in This Experiment.....	71
Table 4.2. Biochar properties used in the experiment.....	78
Table 4.3 Average growth rate per year of pasture in Tokomaru soil.....	79
Table 4.4 Average total DM of pasture in Tokomaru soil.....	80
Table 4.5. Average growth rate per year of pasture in Motuiti soil.....	81
Table 4.6 Total average DM of pasture in Motuiti soil.....	82
Table 4.7 Estimation of live and dead roots amount in corresponding TK soil layer.....	83
Table 4.8 Estimation of live and dead roots amount in corresponding MS soil layer.....	85

## List of Pictures

Picture 4.1. Sampling of Tokomaru silt loam soil .....	72
Picture 4.2. Soil column with TDR installed .....	73
Picture 4.3. Lateral drip irrigation machine that used in the experiment .....	75

