

Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

$\frac{87}{395} - \frac{1}{4}$

SELECTED SOIL PHYSICAL PROPERTIES AND
THEIR AFFECTS ON CEREAL YIELDS IN THE
MANAWATU-RANGITIKEI REGION, NEW ZEALAND

A thesis presented in partial fulfilment
of the requirements for the Degree of
Master of Science in Soil Science
at Massey University.

Gerard John Grealish

1986

ABSTRACT

The Manawatu-Kairanga-Rangitikei region is now a major cropping district in New Zealand. Expansion and intensification has led to a need for more specific information on soil physical properties and how these properties interact with crop yield and soil management.

Soil physical properties largely determine the rooting depth and available water storage capacity of a soil-crop system. Compacted subsoils ($1.5-1.7 \text{ Mg/m}^3$), low saturated hydraulic conductivity (0-10 mm/hr), and poor aeration (0-5% large pores) were the probable causes restricting root depth in the six high terrace soils (Kiwitea mottled, Marton, Tokomaru silt loams) investigated. The two river plain soils (Kairanga silt loams) gave results which indicated a more suitable rooting environment than the high terrace soils.

Restricted rooting depth led to low (65-80mm) total available water contents (TAWC) for the high terrace soils and higher, but more variable, TAWC (80-116mm) for the Kairanga soils.

A simple soil water balance model allowed soil water storage and climate to be integrated to estimate periods of moisture stress. In the year of this study (1985/86) there was a range in moisture stress days (0-27 days) dependant on soil type. However, there was no correlation between the computed number of moisture stress days and crop yield. This was due to an unusual wet spring-summer growth

season. Thus other factors, probably related directly and indirectly to poor drainage and aeration, affected yield more than moisture stress. Extended to different climatic seasons, the model predicted that 25-64 moisture stress days would occur in a drier season, depending on soil type. This is predicted to cause a 40% and 20% reduction in yield due to moisture stress for the high terrace soils and a Kairanga soil respectively.

ACKNOWLEDGEMENTS

I wish to express hearty thanks to my supervisors; to Dr. A.S. Palmer for his continual guidance, encouragement, and friendship; and to Dr. P.E.H. Gregg and Dr. D.R. Scotter for their invaluable assistance and constructive criticism during my work.

I would also like to thank M. Eggels for his assistance with some computing; Dr. N.J. Withers, Dr. J.M. de Ruiter and East Coast Fertilisers for providing information used in this study; and to the farmers who allowed their soils to be sampled.

Table of Contents

ABSTRACT.....	ii
ACKNOWLEDGEMENTS.....	iv
TABLE OF CONTENTS.....	v
LIST OF FIGURES.....	viii
LIST OF TABLES.....	xi
 CHAPTER 1 	
INTRODUCTION AND OBJECTIVES.....	1
1.1 Introduction.....	2
1.2 Objectives.....	5
 CHAPTER 2 	
SITE SELECTION.....	6
2.1 Introduction.....	7
2.2 Barley.....	7
2.3 Site Selection.....	8
2.4 Site - Location, History, and Yield.....	11
2.5 Soil Conditions.....	14
2.5.1 Soil Chemical Fertility.....	15
 CHAPTER 3 	
SOIL PHYSICAL FERTILITY.....	18
3.1 Introduction.....	19
3.2 Methods.....	22
3.2.1 Profile Descriptions.....	22
3.2.2 Dry Bulk Density.....	22
3.2.3 Particle Density.....	23
3.2.4 Saturated Hydraulic Conductivity.....	24
3.2.5 Water Retention Characteristics.....	25
3.2.6 Total Carbon.....	26
3.2.7 Root Mass.....	27
3.3 Results.....	27
3.3.1 Soil Profile Descriptions.....	27
3.3.1.1 Kiwitea mottled silt loam.....	28
3.3.1.2 Marton silt loam.....	28
3.3.1.3 Tokomaru silt loam.....	29
3.3.1.4 Kairanga silt loam.....	29
3.3.2 Dry Bulk Density.....	38
3.3.3 Particle Density.....	41

3.3.4	Saturated Hydraulic Conductivity.....	41
3.3.5	Water Retention Characteristics.....	43
3.3.6	Total Carbon.....	48
3.3.7	Root Mass.....	50
3.3.8	Summary of Results.....	52
3.4	Review of Soil Physical Properties and Discussion of Results.....	54
3.4.1	Soil Temperature.....	54
3.4.2	Soil Strength.....	57
3.4.3	Water Movement.....	60
3.4.4	Soil Aeration.....	63
3.4.5	Soil Moisture.....	69
3.4.6	Structure Stability.....	71
3.5	Conclusions.....	72

CHAPTER 4

SOIL WATER STORAGE.....	74
4.1 Introduction.....	75
4.2 Soil Water Limits.....	77
4.2.1 Upper Limit.....	77
4.2.2 Stress Point.....	79
4.2.3 Lower Limit.....	79
4.2.4 Rooting Depth.....	81
4.3 Available Water Capacity.....	82
4.3.1 Readily Available Water Capacity.....	82
4.3.2 Total Available Water Capacity.....	83
4.4 Results.....	83
4.5 Discussion.....	85

CHAPTER 5

SOIL WATER BALANCE.....	87
5.1 Introduction.....	88
5.1.1 Soil-Plant-Atmosphere.....	90
5.1.2 Water Stress.....	91
5.1.3 Water Stress - Nutrient Availability.....	92
5.1.4 Transpiration and Yield.....	93
5.2 Water Balance Construction.....	95
5.2.1 Introduction.....	95
5.2.2 Evapotranspiration.....	97
5.2.2.1 Non-potential Evapotranspiration.....	99
5.2.2.1.1 Transpiration.....	100
5.2.2.1.2 Soil Evaporation.....	103
5.2.3 Running The Model.....	104
5.3 Results - 1985/86 Season.....	105
5.4 Discussion - 1985/86 Season.....	112
5.5 Extension.....	118
5.5.1 Introduction.....	118

5.5.2	Results.....	119
5.5.3	Discussion.....	123
5.6	Conclusions.....	125

CHAPTER 6

SYNTHESIS.....	128
6.1 Introduction.....	129
6.2 An Overview.....	129
6.2.1 Factors affecting yield.....	129
6.2.2 Soil types.....	130
6.2.3 Soil physical properties.....	130
6.2.4 Soil water storage.....	132
6.2.5 Soil-type differences.....	133
6.2.6 Water balance model.....	133
6.2.7 Moisture stress and yield.....	134
6.2.8 Water balance model extensions.....	135
6.3 Implication Of Soil Physical Fertility To Land Use.....	136
6.4 Further Research.....	138
6.5 Conclusions.....	140

APPENDIX A

Profile Descriptions.....	143
A.1 Kiwitea mottled silt loam (1) (Kiw-1).....	144
A.2 Kiwitea mottled silt loam (2) (Kiw-2).....	145
A.3 Marton silt loam (1) (Mar-1).....	146
A.4 Marton silt loam (2) (Mar-2).....	147
A.5 Tokomaru silt loam (1) (Tok-1).....	148
A.6 Tokomaru silt loam (2) (Tok-2).....	149
A.7 Kairanga silt loam (1) (Kai-1).....	150
A.8 Kairanga silt loam (2) (Kai-2).....	151

APPENDIX B

Summary of Soil Profile Results.....	152
B.1 Kiwitea mottled silt loam (1) (Kiw-1).....	153
B.2 Kiwitea mottled silt loam (2) (Kiw-2).....	153
B.3 Marton silt loam (1) (Mar-1).....	154
B.4 Marton silt loam (2) (Mar-2).....	154
B.5 Tokomaru silt loam (1) (Tok-1).....	155
B.6 Tokomaru silt loam (2) (Tok-2).....	155
B.7 Kairanga silt loam (1) (Kai-1).....	156
B.8 Kairanga silt loam (2) (Kai-2).....	156

BIBLIOGRAPHY.....	157
-------------------	-----

Table of Figures

<u>Figure</u>		<u>Page</u>
1.1	Factors affecting potential crop yield.	3
2.1	Map showing the location of the eight sites.	12
3.1	Important soil physical properties related to some plant physiological processes.	20
3.2	Plate showing cores used for sampling the soil to measure saturated hydraulic conductivity, bulk density, and soil water retention respectively.	23
3.3	Kiwitea-1 soil profile.	30
3.4	Kiwitea-2 soil profile.	31
3.5	Marton-1 soil profile.	32
3.6	Marton-2 soil profile.	33
3.7	Tokomaru-1 soil profile.	34
3.8	Tokomaru-2 soil profile.	35
3.9	Kairanga-1 soil profile.	36
3.10	Kairanga-2 soil profile.	37
3.11	Average bulk density plotted against depth for the eight profiles.	39
3.12	Bar graphs showing the corresponding horizon bulk density at selected depths in the soil profiles.	40
3.13	Particle density plotted against depth.	42
3.14	The range of saturated hydraulic conductivity (K_s) values at sampled depths for each site.	44
3.15a	Soil water retentivity profiles (Volumetric Water Content versus Depth) for the Kiwitea and Marton soils.	46

3.15b	Soil water retentivity profiles (Volumetric Water Content versus Depth) for the Tokomaru and Kairanga soils.	47
3.16	Total carbon percentage for the two topsoil sample depths.	49
3.17	Root weight distribution measured down the profile for the eight soils.	51
3.18	Plate showing water ponded on the soil surface of a Tokomaru silt loam five days after the previous rainfall.	62
3.19	Plate showing compacted soil surface by a harvesting machine wheel.	62
3.20a	Large pore spaces ($>0.06\text{mm}$) important for soil drainage and soil aeration, for the Kiwitea and Marton sites.	66
3.20b	Large pore spaces ($>0.06\text{mm}$) important for soil drainage and soil aeration, for the Tokomaru and Kairanga sites.	67
4.1	Soil physical properties determine available water storage. Combined with climate they may affect crop productivity.	76
5.1	Diagram showing components of the soil water balance.	96
5.2	Relationship between soil water storage and the soil moisture factor.	102
5.3a-h	The soil water balance for each site for the 1985/86 season.	106-109
5.4	Distribution of moisture stress days at each site for the 1985/86 season.	111
5.5	Total number of moisture stress days plotted with yield for the 1985/86 season for all sites.	113

- 5.6 Ratio of actual transpiration and potential transpiration (T_a/T_p) plotted with yield for the 1985/86 season at all sites. 113
- 5.7 Distribution of moisture stress days for the wet (1985/86), average (1984/85), and dry (1983/84) seasons at four selected sites. 121
- 5.8 Ratio of actual transpiration and potential transpiration (T_a/T_p) for the wet (1985/86), average (1984/85), and dry (1983/84) season at four selected sites. 122

Tables

<u>Table</u>		<u>Page</u>
2.1	Summary of mean rainfall and mean temperature data for the spring and summer months at the Marton, Ohakea, and Kairanga meteorological stations.	10
2.2	Sowing and harvesting dates, number of years out of grass, and yield data for the eight soils.	13
2.3	Soil test results, showing nutrient status of soils before sowing.	17
2.4	Fertiliser applied by the farmer for the 1985/86 season.	17
3.1	Monthly long-term soil temperature averages and monthly soil temperature averages for the 1985-86 season, at Marton and Kairanga Meteorological Stations.	56
4.1	Readily available and total available water capacities for the eight sites.	84
5.1	Variation in the total number of moisture stress days for 1985/86 season when available water holding capacities are adjusted by $\pm 20\%$.	115
5.2	Rainfall data from Ohakea showing for the months of November and December.	120