

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.

Massey University Library

Thesis Copyright Form

Title of thesis: The Pattern of Soil Water Extraction
by Individual Kiwifruit Vines.

(1) (a) I give permission for my thesis to be made available to readers in the Massey University Library under conditions determined by the Librarian.

(b) ~~I do not wish my thesis to be made available to readers without my written consent for _____ months.~~

(2) (a) I agree that my thesis, or a copy, may be sent to another institution under conditions determined by the Librarian.

(b) ~~I do not wish my thesis, or a copy, to be sent to another institution without my written consent for _____ months.~~

(3) (a) I agree that my thesis may be copied for Library use.

(b) ~~I do not wish my thesis to be copied for Library use for _____ months.~~

Signed

V. Snow

Date

16/7/87

V. Snow

The copyright of this thesis belongs to the author. Readers must sign their name in the space below to show that they recognise this. They are asked to add their permanent address.

NAME AND ADDRESS

DATE

THE PATTERN OF SOIL WATER EXTRACTION BY

INDIVIDUAL KIWIFRUIT VINES

A thesis presented in partial fulfillment
of the requirements for the Master of Agricultural
Science in Soil Science at
Massey University

VALERIE OLGA SNOW

1987

ABSTRACT

In order to efficiently design and operate irrigation systems water balance studies are needed. To date few of these studies have been carried out on kiwifruit.

Detailed measurements of water extraction were made beneath two 7 year old kiwifruit vines. Under-vine covers were used on these vines to exclude rainfall and irrigation. Measurements of fruit size and leaf water potential were made on the two covered vines and on adjacent irrigated vines. In addition, solar radiation and air temperature were monitored in the orchard block. In concurrent studies, the root distribution of vines in the orchard were determined and heat pulse measurements of sapflow were made.

The water extraction pattern showed little variation with depth to the maximum depth of measurement (2.2 m). There was, however, considerable variation in extraction with horizontal distance away from the vine. This variation may be explained in terms of the root distribution. The soil volume may be divided into the zone of occupation, in which the soil is completely occupied by the plant roots, and the zone of exploration, which is the volume of soil in which there are a few roots but the soil is still largely unexplored. Within the zone of occupation, water is uniformly extracted despite variation in root density. Water appears to be extracted from the zone of exploration primarily by flow of water towards the zone of occupation, where the soil water potential is lower.

The fruit volume and leaf water potential measurements were used to indicate the onset of water-stress. At this time, soil water potential in the zone of occupation was between -40 and -50 kPa. The size of the reservoir of readily available water was found to be at least 2.1 m³ for 7 year old vines, and is projected to rise to a maximum of at least 6.5 m³ in three or so years in this orchard. Whereas the vine canopy may, by management, mature in 3 years, the root system may take 10 years to mature, so irrigation requirements of young vines will be higher than for mature vines. This is contrary to common assumptions made in standard methods for designing horticultural irrigation systems and is due to

changes in the size of the reservoir rather than changes in the rate of water use.

When there is radial variation in water extraction it is important to take account of the variation when calculating volumes of water extracted from the soil. The rate of water use by the vines, as estimated by the water balance method and the heat pulse technique, was found to be considerably lower than that predicted by the equilibrium evapotranspiration rate. This may be due to experimental error, and further work is required to clarify this matter.

ACKNOWLEDGEMENTS

Thanks are due to my supervisors, Dave Scotter (Soil Science Dept., Massey University) and Brent Clothier (Plant Physiology Div., DSIR), who provided not only guidance, but also support and encouragement during the course of the degree. Special thanks to Brent, who managed to maintain good humour throughout, even when left stranded late one evening at the rather distant experimental site. (Thanks also to Penny Clothier who rescued him!)

The research presented in this thesis was a part of a larger investigation into the water economy of kiwifruit. People involved in this research have included Brent Clothier, Steve Green, Tom Sauer, Paul Gandar, Keith Hughes and Howard Nicholson. Thanks are specially due to Brent Clothier, Steve Green and Tom Sauer for assistance with some of the measurements presented in this thesis.

The orchard in which the research was carried out is owned and managed by John and Janice Carson. I thank them for making their orchard available and for their generosity and cooperation during the course of the field work.

The research was jointly funded by the Soil and Water Directorate, Ministry of Works and Development, Wanganui and the Plant Physiology Division, DSIR, Palmerston North. I was based at the latter institution for the duration of the degree and am grateful for the use of the facilities and for the swift action on the parts of the director, Jim Kerr, and Brent Clothier which allowed my involvement with the research programme.

Thanks to John Julian and Peter Menalda for the construction of the under-vine covers. Finally, I would like to thank Jim Watt (Soil Bureau, DSIR, Havelock North) and the SWAMP team who described the soil in the orchard and provided me with an advance copy of the results.

TABLE OF CONTENTS

ABSTRACT ii

ACKNOWLEDGEMENTS iv

TABLE OF CONTENTS v

LIST OF FIGURES vii

LIST OF TABLES x

LIST OF SYMBOLS xi

CHAPTER ONE

INTRODUCTION 1

1.1 Experimental Site Description 3

1.1.1 The Orchard 3

1.1.2 Soil Description 6

CHAPTER TWO

THE SPATIAL PATTERN OF WATER EXTRACTION AND ROOT DISTRIBUTION . . 12

2.1 Introduction 12

2.1.1 Why Measure Water Extraction? 12

2.1.2 How to Measure Water Extraction 13

2.1.3 Symmetry Considerations 13

2.1.4 Measuring Soil Water Content 14

2.1.5 Root Distributions 15

2.2 Methods 17

2.2.1 Under-vine Covers 17

2.2.2 Neutron Probe Measurements 18

2.2.2.1 Neutron Probe Theory 18

2.2.2.2 Access Tube Installation 19

2.2.2.3 Neutron Probe Calibration 21

2.2.2.4 Accuracy of the Neutron Probe Measurements 23

2.2.2.5 Drainage 25

2.2.3 Root Distribution 27

2.3 Results and Discussion 28

2.3.1 Water Extraction Patterns 28

2.3.2 Root Length Density Patterns 33

2.4 General Discussion 34

2.5 Conclusion 39

CHAPTER THREE

THE RESERVOIR OF AVAILABLE WATER	41
3.1 Introduction	41
3.2 Methods	46
3.2.1 Fruit Volume Measurements	47
3.2.2 Pressure Bomb Measurements	50
3.3 Results and Discussion	51
3.3.1 Fruit Volume Measurements	51
3.3.1.1 Irrigated Vines, 1985/86 Season	51
3.3.1.2 Non-irrigated Vines, 1985/86 Season	55
3.3.1.3 Irrigated Vines, 1986/87 Season	58
3.3.1.4 Non-irrigated Vines, 1986/87 Season	60
3.3.2 Leaf Water Potentials	61
3.4 The Lower Limit of Available Water	65
3.5 Recovery from Water Stress	73
3.6 Conclusions	75

CHAPTER FOUR

TEMPORAL PATTERNS OF WATER EXTRACTION	77
4.1 Introduction	77
4.1.2 Measurement and Estimation of Evapotranspiration in Orchards	80
4.2 Methods	81
4.2.1 Micrometeorological Measurements	81
4.3 Results and Discussion	82
4.4 Conclusions	88

CHAPTER FIVE

SUMMARY AND CONCLUSIONS	89
5.1 The Spatial Pattern of Water Extraction	89
5.2 The Size of the Reservoir of Available Water	91
5.3 Vine Water Requirements	92
5.4 Implications for Irrigation System Design and Operation	93
5.5 Further Research Needs	97

BIBLIOGRAPHY

.	99
-----------	----

LIST OF FIGURES

Figure 1.1	Orchard location	4
Figure 1.2	Orchard block layout	5
Figure 1.3	Soil profile pit	7
Figure 1.4	Variation in soil bulk density (ρ_b) with depth . . .	8
Figure 1.5	Soil water rententivity	9
Figure 1.6	Water content of the Westmere silt loam at field capacity	11
Figure 2.1	Cover frame and skirt	17
Figure 2.2	Completed cover	17
Figure 2.3	Diagram of the layout of the under-tree cover and neutron probe access tube positions	20
Figure 2.4	Calibration of the neutron probe	22
Figure 2.5	Water content under vine A at 31/1/86, 7/3/86 and 08/04/86, (a) 0m from vine, (b) 0.5m from vine, (c) 1.0m from vine, (d) 1.5 m from vine, (e) 2.0 m from vine	29
Figure 2.6	Water content under vine A at 5/12/86, 19/12/86 and 27/12/86, (a) 0m from vine, (b) 0.5m from vine, (c) 1.0m from vine, (d) 1.5 m from vine, (e) 2.0 m from vine	30
Figure 2.7	Water content under vine A at 5/12/86, 19/12/86 and 27/12/86, (a) 0m from vine, (b) 0.5m from vine, (c) 1.0m from vine, (d) 1.5 m from vine, (e) 2.0 m from vine	31

Figure 2.8	Water content under vine B at 5/12/86, 19/12/86 and 28/1/87, (a) 0m from vine, (b) 0.5m from vine, (c) 1.0m from vine, (d) 1.5 m from vine, (e) 2.0 m from vine	32
Figure 2.9	The pattern of root distribution around 7 year old vines in J. Carson's orchard	35
Figure 2.10	Soil water deficit, (a) vine A 1985/86, (b) vine B 1985/86, (c) vine A 1986/87, (d) vine B 1986/87	36
Figure 3.1	Device for measureing fruit volume	48
Figure 3.2	Fruit volume for the 1985/86 season	52
Figure 3.3	Fruit growth rate, radiation and data for the 1985/86 season	56
Figure 3.4	Fruit volume for the 1986/87 season	59
Figure 3.5	Diurnal pattern of leaf water potential of the irrigated and coverd vines	63
Figure 3.6	Soil water content and potential at stress point . . .	69
Figure 3.7	Water content difference between "field capacity" and the "stress point" in the 1985/86 season (●) and the 1986/87 season (■)	71
Figure 4.1	Comparison of cumulative evapotranspiration estimated by the water balance technique on vine A (●) and vine B (■) and the equilibrium rate (—) in the 1985/86 season	83
Figure 4.2	Comparison of cumulative evapotranspiration estimated by the water balance technique on vine A (●) and vine B (■) and the equilibrium rate (—) in the 1986/87 season	84

Figure 4.3 Comparison of evapotranspiration estimated by the equilibrium rate (——) or the water balance technique when radial variation is ignored. Extraction at 0.5 (●) or 1 m (■) from vine B, 1985/86 season 87

LIST OF TABLES

Table 3.1 Miscellaneous Fruit Data 57

Table 3.2 Leaf Water Potential Results 62

Table 3.3 Monthly m³ of irrigation water required under
 several combinations of reservoir size and rainfall regime . . 72

LIST OF SYMBOLS

		units
a	fitted constant	
b	fitted constant	
C_r	count rate	counts s^{-1}
E	rate of water vapourisation	mm day^{-1}
ET	rate of evapotranspiration	mm day^{-1}
k	hydraulic conductivity	m s^{-1}
NS	not significant	
NZDT	N. Z. daylight time	
R_n	net radiation	MJ $m^{-2} day^{-1}$
r	radius	m
s	slope of saturation vapour curve	mPa $^{\circ}C^{-1}$
sd	standard deviation	
TDR	time domain reflectometry	
t	time	s
z	depth	m
γ	psychrometric constant	mPa $^{\circ}C^{-1}$
Δ	change with time	
ε	total error on θ	$m^3 m^{-3}$
ε_c	calibration error on θ	$m^3 m^{-3}$
ε_i	instrument error on θ	$m^3 m^{-3}$
ε_l	location error on θ	$m^3 m^{-3}$
ε_s	site error on θ	$m^3 m^{-3}$
θ	volumetric soil water content	$m^3 m^{-3}$
θ_m	measured value of θ	$m^3 m^{-3}$
θ_t	true value of θ	$m^3 m^{-3}$
λ	latent heat of vapourisation	MJ kg^{-1}
ρ_b	soil bulk density	Mg m^{-3}
ψ	soil water potential	kPa
ψ_l	leaf water potential	MPa
ω	gravimetric soil water content	kg kg^{-1}