

THE INFLUENCE OF DIFFERENT CULTIVATION TECHNIQUES
ON CHANGES IN SOIL PROPERTIES AND SOIL MESOFAUNA

BY

David K. Malinda B.Agr.Eng. (U.S.S.R)
Grad. Diploma Dry Land Farming International
(Roseworthy - Australia)

Thesis submitted in total fulfilment
of the requirement for the degree of
Master of Agricultural Science

Department of Soil Science
Waite Agricultural Research Institute
The University of Adelaide

September 1982

C O N T E N T S

	<u>Page No.</u>
<i>LIST OF FIGURES</i>	<i>vi</i>
<i>LIST OF PLATES</i>	<i>viii</i>
<i>LIST OF TABLES</i>	<i>ix</i>
<i>SUMMARY</i>	<i>x</i>
<i>STATEMENT</i>	<i>xi</i>
<i>ACKNOWLEDGEMENT</i>	<i>xii</i>

CHAPTER I

GENERAL INTRODUCTION AND LITERATURE REVIEW	1
1.1 GENERAL INTRODUCTION	1
1.2 REVIEW OF THE LITERATURE	3
1.2.1 Definition of soil structure	3
1.2.2 Development and use of tillage	3
1.2.2.1 Conventional cultivation	3
1.2.2.1.1 Shallow cultivation	4
1.2.2.1.2 Time of tillage	5
1.2.2.1.3 Amount and depth of cultivation	5
1.2.2.1.4 Deep cultivation	6
1.2.2.2 Direct drilling	6
1.2.2.2.1 Development of the technique	7
1.2.2.2.2 Problems associated with the technique	7
1.2.3 Effect of tillage practices on soil properties	8
1.2.3.1 Effect on soil structure	8
1.2.3.1.1 Immediate compaction	9
1.2.3.1.2 Time dependent compaction	14
1.2.3.1.3 Conclusion	16
1.2.3.2 Effect on organic matter	16
1.2.3.2.1 Introduction	16
1.2.3.2.2 Accretion of OM in soil	17
1.2.3.2.3 Fractionation of organic matter	17
1.2.3.2.4 Organic matter and soil aggregation	18
1.2.3.2.5 Effect of cultivation on soil OM	19
1.2.3.3 Effect on soil water	20
1.2.3.3.1 Infiltration	20
1.2.3.3.2 Water store	21

1.2.4	Determination of soil structure	22
1.2.5	Ecology of soil animals	25
1.2.5.1	Geographical distribution	25
1.2.5.2	Spatial distribution	25
1.2.5.3	Activities of soil animals	26
1.2.5.4	Interactions of soil fauna and micro-organisms	28
1.2.6	Effect of soil animals on soil	29
1.2.6.1	Modification and maintenance of soil structure	29
1.2.6.2	Effect on OM	30
1.2.7	Effect of tillage practices on soil fauna	31
1.2.8	Extraction of animals from soil	34

CHAPTER 2

	METHODS OF STUDY FOR FIELD EXPERIMENTS	36
2.1	DESCRIPTION OF SITES AND SOILS	36
2.1.1	Avon	36
2.1.2	Tarlee	37
2.1.3	Waite Institute	38
2.2	DESCRIPTION OF SITE TREATMENTS	38
2.2.1	Avon	38
2.2.2	Tarlee	39
2.2.3	Waite Institute	39
2.3	ESTIMATION OF SOIL ANIMAL NUMBERS AT ALL SITES	40
2.3.1	Plot size and sampling intensity	40
2.3.2	Handling of soil samples	41
2.3.3	Extraction of soil animals	42
2.3.4	Mounting of soil animals	43
2.3.5	Identification of soil animals	43
2.4	EXAMINATION OF SOIL STRUCTURE	43
2.4.1	Measurement of pore size distribution at Avon	43
2.4.1.1	Sampling	43
2.4.1.2	Thin section preparation technique	43
2.4.1.3	Measurements and characterization of thin sections	44

	<u>Page No.</u>
2.4.2 Measurements of total porosity at Avon	46
2.4.3 Measurement of soil strength at Avon	46
2.4.4 Measurement of soil water content	48
2.4.4.1 Introduction	48
2.4.4.2 Avon - Gravimetric method	48
2.4.4.3 Waite Institute - Gravimetric method and Gypsum blocks	49
2.5 MEASUREMENTS OF SOIL TEMPERATURE AT THE WAITE INSTITUTE	49
2.6 EXTRACTION OF LIGHT FRACTION FROM SOIL	52
2.6.1 Introduction	52
2.6.2 Separation of L.F. from soil	52

CHAPTER 3

EFFECTS OF TILLAGE ON ENVIRONMENTAL FACTORS INFLUENCING SOIL FAUNA - RESULTS AND DISCUSSIONS	54
3.1 INTRODUCTION	54
3.2 EFFECT ON SOIL STRUCTURE	54
3.2.1 Porosity at Avon	54
3.2.2 Effect on soil water content	59
3.2.2.1 Introduction	59
3.2.2.2 Avon	59
3.2.2.3 Waite Institute	63
3.3 EFFECT ON SOIL TEMPERATURE AT THE WAITE INSTITUTE	64
3.3.1 Introduction, Results and Discussion	64
3.4 EFFECT ON ORGANIC MATTER	67
3.4.1 Avon	67
3.4.2 Waite Institute	67
3.5 CONCLUSION	70

CHAPTER 4

EFFECTS OF DIFFERENT SEEDBED PREPARATION TECHNIQUES ON SOIL FAUNA - RESULTS AND DISCUSSION	72
4.1 INTRODUCTION	72
4.2 ANIMAL POPULATION AT AVON	72
4.2.1 The effect of DD and CC	72
4.2.2 The effects of seasonal change	75
4.3 ANIMAL POPULATION AT WAITE INSTITUTE - THE EFFECTS OF DIFFERENT TILLAGE IMPLEMENTS AND TWO HERBICIDES APPLIED SEPARATELY	78
4.4 DIFFERENCES BETWEEN AVON AND WAITE INSTITUTE	82
4.5 EFFECTS OF A MIXTURE OF HOEGRASS AND BUCTRIL HERBICIDES	82
4.5.1 Avon	82
4.5.2 Waite Institute	84
4.6 CONCLUSION	88

CHAPTER 5

EFFECTS OF CROP ROTATION AND TRASH DISPOSAL METHODS ON SOIL FAUNA AND PLANT DEBRIS - RESULTS AND DISCUSSION	90
5.1 INTRODUCTION	90
5.2 EFFECT OF ROTATION	91
5.2.1 Tarlee	91
5.2.2 Avon	91
5.2.3 Waite Institute	92
5.3 EFFECTS OF TRASH DISPOSAL AT TARLEE	95
5.4 EFFECT OF REWORKING AT TARLEE	95
5.5 CONCLUSION	98

CHAPTER 6

LABORATORY INVESTIGATIONS INTO THE INDIVIDUAL AND INTERRELATED EFFECTS OF SOME SOIL ENVIRONMENTAL FACTORS ON SOIL FAUNA AND THEIR FEEDING HABITS	99
6.1 EFFECTS OF PORE DIAMETER AND TEMPERATURE ON ANIMAL MOBILITY	99
6.1.1 Introduction	99
6.1.2 Experimental methods	99
6.1.2.1 Trapping of soil animals	99
6.1.2.2 Stabilization of soil aggregates to make pores	100
6.1.2.3 Examination of the pores made by different size aggregates	101
6.1.2.4 Measurement of animal movement through pores made by aggregates	101
6.1.2.5 Measurement of animal dimensions	101
6.1.3 Results and Discussion	101
6.1.3.1 Effect of temperature on animal mobility	101
6.1.3.1.1 Effects of body temperature	101
6.1.3.1.2 Effect of soil temperature	104
6.1.3.2 Pore sizes formed between aggregates (results as measured by Quantimet 720)	104
6.1.3.3 Effect of pore size	106
6.2 EFFECT OF COMPLEXITY OF PATHWAY	106
6.2.1 Introduction	107
6.2.2 Experimental Methods	107
6.2.2.1 Measurements of length of pathway	107
6.2.2.2 Theoretical explanation	108
6.2.3 Results and Discussion	110
6.3 CONTRIBUTION OF SOIL ANIMALS TO DEGRADATION OF PLANT DEBRIS	112
6.3.1 Introduction	112
6.3.2 Experimental Method	112
6.3.3 Results and Discussion	112
6.4 CONCLUSION	115

CHAPTER 7

GENERAL DISCUSSION AND CONCLUSIONS	117
7.1 DIRECT DRILLING	118
7.2 CONVENTIONAL CULTIVATION	119
7.3 EFFECT ON SOIL FAUNA	120
7.4 ACTIVITIES AND IMPORTANCE OF SOIL ANIMALS	122
7.5 PROPOSAL	124
APPENDICES	125
REFERENCES	139

LIST OF FIGURES

<u>Figure</u>		<u>Page No.</u>
1	Forces resulting from the movement of a Mouldboard plough in soil.	10
2	The influence of soil water content on the degree of compactness after a single pass of a 46 kw tractor (mass 4.03t) at 71 cm/hr. over soil of 38% clay content. (After Ljungars, 1977).	11
3	The effect of tyre deformation on contact area.	13
4	The Quantimet 720 (After Bullock and Murphy, 1980).	45
5	Calibration curve for soil gypsum blocks	50
6	Typical thermistor calibration curve for the determination of parameters in equation 12.	51
7	Effect of two seedbed preparation techniques (DD) and (CC) on the pore size distribution in two soil layers as measured by QTM 720 (722). Total porosity calculated from bulk density (PP = Picture points).	55
8	Cone penetrometer resistance for a 30 ⁰ 12.83 mm diameter cone for CC treated sandy loam soil for 3 years (— = SE, n=6).	57
9	Water content of two layers of DD and CC soils at Avon from June to December 1980.	60
10	Water content depth curves for the driest month - December to January 18, 1980 at Avon (---DD, —CC).	61
11	Effect of cultivation on infiltration and movement of water in silt loam soil four days after 49 mm rain fall (% v/v) (Based on Baeumer, 1970).	62
12	Effect of two seedbed preparation techniques on LF content at Avon (June values after pasture phase).	68
13	Significance of the differences between faunal population numbers in two layers of DD and CC treated soils from May-August at Avon. Climatic data is included.	76
14a	Total numbers of Collembola (each depth 15 samples) in samples taken from two layers of variously treated sites at the Waite Institute between May - August, 1981. — = SE (C-control U ₁ -tine cult. -U ₂ -disk plough -U ₃ -mouldboard plough U ₄ -buc-tril U ₅ -hoe grass).	80

<u>Figure</u>		<u>Page No.</u>
14b	Total numbers of mites (each depth 15 samples) in samples taken from two layers of variously treated sites at the Waite Institute between May-August 1981.	81
15	Soil animal populations before and after a herbicide mixture (hoegrass and buctril) was applied to DD and CC plots at Avon.	83
16	Population density of soil animals before and after a mixture of herbicides (hoegrass and buctril) was applied at the Waite Institute.	85
17a	Effect of crop rotation, stubble handling methods and extensive use of agricultural tools on soil animals at Tarlee.	96
17b	Same as Fig. 17a.	97
18	Effect of body temperature on the activities of soil animals in various size pore spaces (I-7°C, II-16°C). (size of aggregates given).	102
19	Effect of soil temperature on activities of soil animals (size of aggregates given).	103
20	Relationship at different temperatures between soil pore size and movement of Poduridae (Collembola) with varied body diameter sizes. I=body temperature 7°C, II-body temperature 16°C, III-soil temperature between 25-45°C, IV-soil temperature 25-35°C.	105
21	Aggregate beds showing complexity of pathway from point A to point B.	107
22	Diffusion theory	108
23	The normal distribution curve.	109
24	Rate of diffusion (emergence) of soil animals through different sized aggregate beds measured at one hour intervals.	111

LIST OF PLATES

<u>Plate</u>		<u>Page No.</u>
1	Comparison between pores (voids) produced by DD and CC at Avon (July 1980 samples)	58
2	Implements used in different seed-bed preparations (A,B,C,D) and comparisons of direct drilling and conventional cultivation (E,F).	65
3	Appearance of leaf sections of <i>Verbenaceae</i> fed to soil animals, magnified 35X. Dark areas represent leaf veins and intact parts of the leaf. Lighter areas represent holes in the leaf and areas eaten by animals.	114
4	Appearance of soil surface after different methods of trash disposal (A,B,C,) and three weeks later following rainfall (A,B,C).	121

LIST OF TABLES

<u>Table</u>		<u>Page No.</u>
1	Total soil water store (0 to 1m) and grain yield for Red-brown earths and associated soils in south-eastern Australia. (After Greacen, 1981).	22
2	Classification of soil pores (Greenland, 1977) used as a basis for classifying soil animals.	32
3	Physical properties and organic carbon content of Avon soil.	36
4	Physical properties and organic carbon content of Tarlee soil.	37
5	Physical properties and organic carbon content of Waite soil.	38
6	Plot size and animal sampling intensity for Avon, Tarlee and Waite Institute.	41
7	Equilibrium infiltration rate mm/hr (measured in the 4th hour after the start of infiltration). (After Aremu, 1979).	63
8	Effect of primary tillage on water content of Urrbrae fine sandy loam	64
9	Comparison of variation in soil temperature at 2 depths at the Waite Institute after implements were used for primary cultivation and after the use of a herbicide to kill broad leaved weeds.	66
10	Correlation between soil animal population and light fraction (OM) changes at Avon.	69
11	Effect of 3 different tillage implements and 2 herbicides on light fraction content at the Waite Institute (n = 8).	69
12a	Total numbers of groups of soil animals extracted from DD plots at Avon during the period 1980-1981 (data given as totals from 15 subsamples) to get population density = $\frac{N}{15} \times 500 \text{ m}^{-2}$	73
12b	Total numbers of groups of soil animals extracted from CC plots at Avon during the period 1980-1981 (data given as totals from 15 subsamples), to get population density = $\frac{N}{15} \times 500 \text{ m}^{-2}$	74

<u>Table</u>		<u>Page No.</u>
13	Total numbers of soil fauna other than Collembola recorded at Avon (total from 30 cores).	77
14	Total animals extracted from Urrbrae soil.	86
15	Mean (\pm SE) numbers of mites and Collembola/core (to get numbers per m ⁻² multiply by a factor 500) and L.F. content (%) at three sites carrying different crop rotations.	93
16	Effect of rotation on light fraction content and the relationship (R) between LF and soil fauna at the Waite Institute.	94
17	Pore sizes produced by different size aggregates as shown by Quantimet 720.	106
18	Length of pathway from point A to point B (see Fig.21) formed between aggregates.	110
19a	Increase in numbers of Astigmata (M) and Poduridae (C) for a period of 9 weeks feeding on common Lantana.	113
19b	Correlation between distance travelled by soil animals during microscopic examination and the amount of leaf consumed during the culture period.	115
20	Wheat plants which lodged (% of total plants) as a result of Take-all fungus, after different crop rotations and cultivation or DD.	119

S U M M A R Y

A review of the effect of different seedbed preparation techniques on soil physical properties and soil fauna is presented. Field work on the subject was carried out at 3 sites in South Australia; Avon, Tarlee and the Waite Institute.

At Avon, the effect of direct drilling and conventional cultivation on the distribution of soil pores $>40 \mu\text{m}$ was considered to be an appropriate study. Pores $>40 \mu\text{m}$ are considered to drain the soil of excessive water, and the larger pores serve as a habitat for the mesofauna which are 200-600 μm in diameter or about the same diameter as roots of cereal plants. Measurement of pore size distribution was made using an image analysis computer directly on thin sections. Total porosity was calculated from the bulk density of the soil.

The results indicate that conventional cultivation produced more pores in the 0-4 cm soil layer compared with direct drilling, but the pores were unstable. Also, conventional cultivation caused a compacted layer to develop in the 4-8 cm layer (and deeper) with about 50% of the pores $>40 \mu\text{m}$ in diameter. Results from direct drilling, however, indicate a stable continuous porosity throughout the 0-8 cm layer.

Macro-organic matter was extracted from soil by a flotation method using ZnBr_2 . The results indicate that much of the leaf material remained on the soil surface after direct drilling but not after conventional cultivation. However, the total macro-organic matter content to a depth of 8 cm did not differ between the two treatments.

The effects of different implements were compared at the Waite Institute. As expected the Mouldboard plough buried plant residues whilst other treatments distributed them in and over the soil surface.

Soil which was direct drilled had a higher water content than conventional cultivated soils, especially during drier periods. This may have been influenced by the differences in porosity and distribution of organic matter in the two soils. Determination of the effects of 4 treatments on both water content and soil temperature were made at the Waite Institute. Soils which were disc ploughed and soils treated with herbicide had lower water contents and temperatures than soils tilled with tined implements and a Mouldboard plough.

The effect of direct drilling, conventional cultivation and single runs with different implements on soil structure and macro-organic matter was related to the populations and distribution of soil animals. The deleterious effect of conventional cultivation on soil fauna was probably a result of changed soil structure and macro-organic matter (quality and distribution). The effect was greater than that of direct drilling which included the toxicity of the herbicides used.

Crop rotation may or may not be suitable for the restoration of large populations of soil animals. Permanent and annual pastures were found to favour soil animals, probably due to the availability of plant litter and a favourable micro-environment. A rotation including a fallow period showed the most deleterious effect on both soil animals and macro-organic matter.

The disposal of trash by different methods after harvesting a crop, i.e. rotary hoe (incorporation), burning or retention on the soil surface, was investigated at Tarlee. The results indicate that trash retention

favoured soil animals since significantly more animals were found after trash retention than other treatments.

The movement of soil animals in beds of soil aggregates and the ability of mites and Collembola to degrade leaves was also examined. Poduridae (Collembola) were used to investigate movements of animals in aggregates because they move faster than mites. The results indicate that fewer animals found their way through beds of smaller aggregates. Increasing temperatures and the drying of soil aggregates from top to bottom, and the resultant low humidity created in the aggregates, also affected the animal movements.

To test the effect of the soil mesofauna on the degradation of plant materials, leaves from common Lantana were observed in culture tubes, together with selected animals. The leaf area consumed in unit time by Astigmata (mites) and Poduridae (Collembola) was measured: Astigmata were found to consume more than Poduridae.

It is concluded that in the South Australian environment mites and Collembola may be as beneficial to agricultural soils as earthworms and termites.

S T A T E M E N T

This thesis contains no material which has been accepted for the award of any other degree or diploma in any University or College, and this thesis contains no material published previously or written by any other person, except where due reference is made in the text of the thesis.

Any assistance received in preparing this thesis, and all sources used, have been acknowledged.

SEPTEMBER, 1982

DAVID K. MALINDA

ACKNOWLEDGEMENTS

I wish to thank my supervisors Professor J.M. Oades and Dr. B.R. Hutson for their interest, invaluable discussions and guidance throughout this project. Grateful acknowledgement is made to C.S.I.R.O. in particular Dr. A.D. Rovira and his staff for allowing me to carry out my experiments at their research site at Avon. Also, for the same reason, grateful acknowledgement is due to the South Australian Department of Agriculture, in particular Mr. J. Schultz (Tarlee).

I thank Dr. Jarvis of Flinders University, Medical School, for showing me how to operate the Quantimet and allowing me to use other facilities. Also, grateful acknowledgement is due to Mrs. Greenslade and David Lee of the South Australian Museum for their help in identifying some of the species of Collembola and Mites; Dr. J.S. Hewitt for helping me with the mathematical model described in Chapter 6.

I am highly indebted to the F.A.O. for funding my study and stay in Australia and my Government, in particular the Ministry of Agriculture for allowing this study and securing my job.

I would like to acknowledge the following people: Mrs. Brock for time devoted to typing this project; Mr. B.A. Palk for initial preparation of some of the photographs; staff of the Biometry Section, in particular Mr. T. Hancock and Miss P. Phillips for their time spent with me analysing the data; my colleagues for helpful discussions on the project matter.

The patience of my Mother shall never be forgotten for the time she has not seen me.