THE EFFECT OF DAIRY, PIGGERY AND WOOL SCOUR EFFLUENTS ON WILLOW GROWTH AND THE SOIL CHARACTERISTICS

A thesis presented in partial fulfillment of the equirements for the degree of Master of Applied Science in Soil Science at Massey University, Palmerston North, New Zealand

Youwei Lu

1997

ACKNOWLEDGMENTS

I would like to express my sincere thanks and appreciation to a number of people for their contribution towards the completion of this thesis. In particular:

Firstly and most importantly, my chief supervisor Dr. N. S. Bolan for organizing and arranging a MApplSc Programme for me to pursue, and for his enthusiastic encouragement and stimulation, great patience and warm guidance, and understanding during my studies.

Professor Russ Tillman, for his supervision, encouragement and patience during my studies.

Associate Professors. P. E. H. Gregg and Mike Hedley and Dr. Max Turner for their valuable guidance and patience during my studies.

Dr. Colin Stace (AgResearch, New Zealand Agriculture Research Institute Ltd, Palmerston North, New Zealand) for providing willow cutting and initial suggestions on establishment of the greenhouse experiment.

Mr. Lance Currie, Mr. Bob Toes, Mr. Ian Furkert, Mrs. Glenys C. Wallace and Mrs. Ann West for their assistance in the laboratory experiments and all my fellow postgraduates for their help and friendship.

All the staff of the Department of Soil Science for their friendliness and their innumerable helps and generous support during this study.

Lastly, my immense appreciation is to my family and my wife Cai Li and son Zhijei for their encouragement and support in many ways.

Thanks also to all people who offered assistance to me but I fail to name individually here.

The effect of dairy , piggery and wool scour effluents on willow growth and the soil characteristics

ABSTRACT

Restrictions on the disposal of agricultural effluents to the waterway means that alternative land based outlets are required in New Zealand. Willow, as a short forest rotation, represents a significant land use that could produce a high dry matter and benefit from the application of effluent irrigation. However, there has been little information on the effect of effluent irrigation on the growth of willow and the removal of nutrients.

In order to assess the effects of dairy, piggery and wool scour effluents on willow growth, a greenhouse experiment was established using the Manawatu sandy fine loam soil. A complete nutrient solution and nutrient - free tap water treatments were also included in addition to the effluent treatments. The design of the experiment was a 5 x 2 factorial combination of treatments with four replications in randomized blocks. Two factors (effluents and irrigation rates) each with 5 levels were examined, the levels of irrigation were 12.5 mm, 25 mm, 37.5 mm, 50 mm and 62.5 mm per fortnight. The plant growth, production and macro-nutrients accumulation, and the soil pH, electrical conductivity, and total N, P and cations were monitored

Irrigation with effluents affected the growth of willow cutting. The piggery and dairy effluent irrigation increased the willow growth and nutrient accumulation followed the increase in DM yield. The piggery and dairy irrigation accounted for 32% and 18% increase in total DM yield over tap water; while the wool scour effluent resulted in 17% decrease in comparison with tap water. Irrigation with dairy, piggery and wool scour effluents onto the Manawatu fine sandy loam soil, caused a significant increase in pH and EC. The significant change in pH and EC was attributed to the soluble salts in these effluents, especially K in the wool scour effluent. The recovery of N from these effluents was very small and was less than that of P and K in soil.

Chemical analysis of willow, treated with dairy, piggery and wool scour effluents up to 8 weeks, showed a relatively high concentration of N, P and K in leaf, and had a very high K and a very low Mg concentration in leaf with wool scour effluent irrigation. However, the efficiency of the N, P and K nutrient accumulated by willow was inversely related to the concentration of these effluents and the DM yield of willow cutting was positively related to the irrigation rates. It was evident that willow cutting was too young to require a large quantity of nutrients at the early growth stage and there was a risk of nutrient loss with increasing irrigation rate. The application of wool scour effluent caused a very high pH and EC, and the willow cutting growth decreased at > 37.5 mm/fortnight irrigation rates. The reasons for the detrimental effects of wool scour effluent on soil properties and willow growth need to be investigated further. The results suggested that it is possible to enhance the willow growth and adjust the soil fertility by application of dairy and piggery effluents irrigation.

TABLE OF CONTENTS

Page

ABSTRACT i

ACKNOWLEDGMENT iii

TABLE OF CONTENTS iv

LIST OF TABLES viii

LIST OF FIGURE x

LIST OF PLAT xi

LIST OF APPENDIX xi

CHAPTER ONE:

INTRODUCTION

1.1 BACKGROUND 1

1.2 OBJECTIVES 2

1.3 STRUCTURE OF THE STUDY 3

CHAPTER TWO:

LITERATURE REVIEW

2.1 INTRODUCTION 4

2.2 SOURCE OF WASTE EFFLUENTS IN NEW ZEALAND 4

2.2.1 Municipal sewage effluent 4

2.2.2 Industrial waste effluents 6

2.2.3 Agricultural waste effluents 7

2.3 TREATMENT OF WASTE EFFLUENT 8

2.3.1 Two ponds system 8

2.3.2 Land application 12

2.4 SECONDARY-TREATED EFFLUENT DISCHARGE TO WATER 14

2.5 WASTE EFFLUENT UTILIZATION IN AQUACULTURE 15

2.6 EFFECTS OF LAND APPLICATION OF WASTE EFFLUENTS ON PLANT 17

2.6.1 Production 17
2.6.2 Physiological and ecological response of plant 18
2.7 EFFECTS OF LAND APPLICATION OF WASTE EFFLUENTS ON SOILS AND THE ENVIRONMENT 19
2.7.1 Soil chemistry 19
2.7.2 Nitrogen 21
2.7.3 Phosphorus 22
2.7.4 Soil pH 23
2.7.5 Exchangeable cation 23
2.7.6 Soil biology 24
2.7.7 Heavy metals 24
2.7.7.1 Metal leaching 25
2.7.7.2 Effects of metals on soil biological activity 25
2.7.8 Organics 26
2.7.9 Soil structural properties 26
2.8 CONCLUSIONS AND FUTURE RESEARCH NEEDS 27

CHAPTER THREE:
MATERIALS AND METHODS

3.1 MATERIALS 29
3.1.1 Soil 29
3.1.2 Plant 29
3.1.3 Effluents 29
3.2 METHODS 30
3.2.1 Experimental design 30
3.2.2 Collection of soil and plant samples 31
3.2.2.1 Soil sampling 31
3.2.2.2 Plant sampling 31
3.2.3 The measurement of shoot growth and root length 32
3.2.31 Shoot length 32
3.2.32 Root length 32

3.2.4 Soil and plant for chemical analysis 32
3.2.4.1 pH 32
3.2.4.2 Electrical conductivity 33
3.2.4.3 Soil exchangeable K, Na, Ca and Mg cation 33
3.2.4.4 Soil and plant for total N and P 34
3.2.4.5 K, Ca and Mg in plants 34
3.2.5 N, P, K, Na, Ca and Mg in effluents 35
3.2.6 Statistical analyses and curve fitting procedures 36

CHAPTER FOUR:

RESULTS AND DISCUSSIONS

4.1 GROWTH RESPONSE OF WILLOW CUTTING TO EFFLUENT IRRIGATION
4.1.1 Effect of effluent on shoot growth 37
4.1.1.1 At two weeks after irrigation 37
4.1.1.2 At five weeks after irrigation 39
4.1.1.3 At eight weeks after irrigation 40
4.1.1.4 Explanation of effect of different effluents on willow short growth 42
4.1.2 The effect of effluents on diameter of willow cutting 46
4.1.3 Root mass and length 50
4.1.4 Effect of effluent on dry matter DM yield 52
4.1.4.1 Aboveground DM yield of willow cutting 52
4.1.4.2 Root DM yield 54
4.1.4.3 Total DM yield of willow cutting 55
4.1.5 Effect of effluents on macro-nutrient uptake by willow cuttings 57
4.1.5.1 Nutrient concentration in leaf 57
4.1.5.2 Nutrient uptake 59
4.2 SOIL CHARACTERIZATION 64
4.2.1 pH 64

4.2.1.1 pH of the effluents 64
4.2.1.2 Effect of effluent irrigation on soil pH 64
4.2.1.3 Explanation for effect of effluent irrigation on soil pH 65
4.2.1.4 Implication of the effluent irrigation on soil pH 66
4.2.2 Electrical conductivity 67
4.2.2.1 Electrical conductivity of the original effluents 67
4.2.2.2 Electrical conductivity of the soils 68
4.2.2.3 Explanation of the effect of the effluent irrigation on the soil electrical conductivity 68
4.2.2.4 Implication of the effect of the effluent irrigation on soil electrical conductivity 69
4.2.3 Total N and P 70
4.2.3.1 Total N and P content of the effluent 70
4.2.3.2 Effect of different effluents on the N content of the soil 72
4.2.3.3 Effect of different effluents on the P content of the soil 73
4.2.3.4 Explanation of the effect of effluent irrigation on the soil N and P 73
4.2.3.5 Implications for soil N and P of effluent irrigation 74
4.4 THE EFFECT OF DIFFERENT EFFLUENT AND IRRIGATION RATE ON THE BASIC CATIONS 75
4.4.1 Potassium 75
4.4.2 Exchangeable Na 77
4.4.3 Calcium 78
4.2.4 Magnesium 78

CHAPTER FIVE:

CONCLUSION AND RECOMMENDATIONS

REVIEW OF LITERATURE 82
EFFLUENT IRRIGATION 83
RECOMMENDATIONS FOR FUTURE WORK 85
REFERENCES 86

LIST OF TABLES

TABLE ..... Page

Table 2.1. Composition of sludge or effluents from a few selected waste sources in New Zealand (Carnus 1994; Hart and Speir 1992) 7

Table 2.2 Chemical analysis of some effluents (mg L^{-1}) (Longhust 1981; Johnson and Ryder 1988) 8

Table 2.3 Some effects of stocking fish in waste treatment ponds 16

Table 2.4 Nutrient status of soil (0 - 15 cm) after 80 years of meatworks effluent application (Keeley and Quin 1979) 20

Table 4.1 The mean of net shoot growth (mm) at 2, 5 and 8 weeks after effluent treatments. 38

Table 4.2 The mean of diameter of willow cutting (mm) after different effluent and irrigation rate treatments 47

Table 4.3 The mean of DM yield of willow (g/pot) at each effluent treatment for all irrigation levels. 52

Table 4.4 The mean of DM yield of willow (g/pot) at each irrigation level for all effluents 56

Table 4.5 The average nutrient concentration of the willow leaf with different effluent treatments 58

Table 4.6 The concentration of macro-nutrients in effluents 58

Table 4.7 Nutrients uptake (g/pot) by willow cutting with different effluent treatment 63

Table 4.8 The pH of the original effluents and the soil treated with the effluent 64

Table 4.9 EC of the original effluent samples and soils treated with the effluents

Table 4.10 Total nitrogen and phosphorus content of the effluent and soil treated with the effluents. 70

Table 4.11 The exchangeable K of original effluent and the soil treated with the effluents. 75

Table 4.12 The New Zealand Soil Bureau ratings for Ca, Na, K and Mg content of new Zealand soils (Blakemore *et. al.*, 1987) 80

Table 4.13 The mean exchangeable K, Ca, Mg and Na in soil treated with different effluent irrigation for 8 weeks. 81

LIST OF FIGURES

FIGURE		Page
Figure 2.1	Two pond system for Dairy & Piggery effluent treatment (Bolan *et. al.*, 1996)	10
Figure 2.2	Schematics summary of modifications, "add-ins" and "add-ons" to existing 2-stage dairy shed wastewater treatment ponds (Sukias *et.al.*,1996)	11
Figure 2.3	Effect of dairy shed effluent and water on seasonal pasture production (mean of four year data) (Robaerts *et. al.,1992*)	17
Figure 4.1	The effect of different effluents and irrigation rates on net shoot growth	41
Figure 4.2	The effect of different effluents on willow shoot growth (12.5 mm/fortnight)	44
Figure 4.3	The effect of different effluents on willow shoot growth (25 mm/fortnight)	44
Figure 4.4	The effect of different effluents on Willow shoot growth (37.5 mm/fortnight)	45
Figure 4.5	The effect of different effluents on Willow shoot growth (50 mm/fortnight)	45
Figure 4.6	The effect of different effluents on Willow shoot growth (62.5 mm/fortnight)	46

Figure 4.7 The effect of the different effluents on the diameter of willow cutting with combination of irrigation rates 47

Figure 4.8 The effect of irrigation rate and effluents on aboveground DM yield 53

Figure 4.9 The effect of irrigation rate and different effluents on root DM yield 54

Figure 4.10 The effect of irrigation rate and different effluents on total DM yield 55

Figure 4.11 K uptake of willow cutting (g/pot) 61

Figure 4.12 N uptake of willow cutting (g/pot) 62

Figure 4.13 P uptake of willow cutting (g/pot) 62

LIST OF PLATES

Plate 1 The effect of different effluents on shoot growth 48

Plate 2 The effect of different effluent on root growth 51

LIST OF APPENDIX

Appendix 4.1 97

Appendix 4.2 98

Appendix 4.3 99

Appendix 4.4 100