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.
ROW SPACING AND SEEDING RATE INTERACTIONS IN PERENNIAL RYEGRASS AND TALL FESCUE SWARDS ESTABLISHED BY DIRECT DRILLING (NO-TILLAGE)

A Thesis presented in partial fulfilment of the requirements for the degree of Doctor of Philosophy at Massey University, Palmerston North New Zealand

by

John-Paul Praat,

1995
ABSTRACT

Direct drilling is a popular and cost-effective method of introducing new, more productive pasture species into existing pasture on farms in New Zealand. The technique conserves both time and money, reduces moisture loss and the risk of soil erosion and offers some management benefits in intensive agricultural systems.

Seed drills in New Zealand commonly used for pasture establishment sow seeds in rows at 150 mm centres. While this is an acceptable row spacing for cereal crops, eg. barley and wheat, closer row spacing has been proposed for establishing pastures. However, little research has been carried out to determine optimal row spacing or seeding rates. The benefit of cross-drilling with two passes of the drill, which is a practice thought to overcome the perceived inadequacies of 150mm row spacing, is also uncertain. This study was designed to investigate the effects of row spacing and cross-drilling, and the relative importance of plant population per unit area and per unit length of drill row on pasture establishment and development.

Single pass sowing, at both 150 and 75mm row spacings together with cross-drilling were compared in an autumn sown field experiment. Two species of contrasting establishment vigour, perennial ryegrass (*Lolium perenne* L.) and tall fescue (*Festuca arundinacea* Schreb.) and two seeding rates (12 and 23 and 17 and 31 kg ha\(^{-1}\) for perennial ryegrass and tall fescue respectively) were also compared. The trial was grazed by dairy cattle throughout the measurement periods.

Emergence of 84 and 71 % of sown perennial ryegrass and tall fescue seed respectively, resulted in establishment of approximately 400-500 and 700-800 seedlings m\(^{-2}\) for medium and high seeding rates respectively for both species. Two years after sowing, medium to high seeding rates offered no advantage in terms of weed suppression or yield compared with low seeding rates.

Cross-drilling offered no advantage for either species. Total herbage yield and the proportion of sown species was the same for perennial ryegrass and tall fescue established in either cross-drilled or 150 mm rows. This was the most important result, as far as the farmer is concerned, with potential cost savings of up to $100 per hectare by not carrying a second pass of the seed drill required for cross-drilling.
The establishment performance of tall fescue in terms of herbage mass and suppression of weeds in the sward was initially improved with closer row spacing. These benefits were not apparent for perennial ryegrass. The advantage gained for fescue from reduced row spacing declined with time and by the second spring after sowing no difference was apparent between 150 and 75mm row spacing treatments. Thus, overall, drilling method had only a minor influence on botanical composition.

Tall fescue was slower establishing and had more clover and weed in the sward compared with perennial ryegrass. This contrast in growth revealed the subtle influences of drilling method and seeding rate on pasture composition.

A second trial, sown in the subsequent autumn, investigated the use of nitrogen with tall fescue at the time of sowing in both single pass and cross-drilling. The results supported those found for the effects of drilling pattern in the first trial. The use of nitrogen fertiliser in the damp, cool conditions of late autumn did not benefit sward development. Emergence of tall fescue was poorer at this time.

In contrast to the results of Trial 1, increasing the seeding rate resulted in increases in initial seedling population and improved the performance of tall fescue. There was a higher proportion and herbage mass of sown species in the sward sown at the higher seed rate. This suggests that higher seeding rates may be required for tall fescue as conditions at sowing become cooler. However, the early advantage from the higher seeding rates was not apparent 10 months after sowing.

Clover emergence was low at 46 and 52% of sown viable seed for the first and second trials respectively. However, a clover seedling population in excess of 150 plants m⁻² was established in both trials which proved to be an adequate population for development of productive pasture.

Drills designed for sowing aggressive species such as perennial ryegrass need not incorporate the option of reducing row spacing from the common 150mm with the subsequent cost disadvantages. However, the option of reduced row spacing may be appropriate for drills designed for sowing less vigorous alternative species such as tall fescue. Increased seeding rates and cross-drilling should not be necessary for successful establishment of a productive pasture sward of temperate species. This leads to improvements in efficiency of seed drill operation in the field.
I wish to express my sincere gratitude for the guidance and encouragement given me by my supervisors Associate Professor C.J. Baker, Mr W.R. Ritchie and Professor J. Hodgson. Their comments, suggestions and willing help was gratefully appreciated especially Mr Ritchie from whom I received inspiration and constructive criticism, especially in the early stages.

Appreciation is extended to the staff of the Agricultural Machinery Research Centre, especially Mr C.D. Kernohan and Plant Science field technicians headed by Mr T. Lynch who provided assistance with field and laboratory work. Appreciation is also extended to fellow postgraduate students.

Mr G. Arnold is acknowledged for his advice and assistance in planning of trials and statistical analysis of data.

The Massey University Research Fund and C. Alma Baker Trust are thanked for their financial support of this study.

Special thanks go to my wife Sue for the support and patience provided to me throughout this study.

For the support, encouragement, understanding and assistance that my family and friends have given me, my appreciation and sincere thanks is expressed. A special thanks also to Berwick Settle, Tony Hadfield and Simon Berry, who have been supportive throughout.
# TABLE OF CONTENTS

Abstract .................................................................................................................................................. i
Acknowledgements ................................................................................................................................. iii
Contents .................................................................................................................................................. iv
List of Tables .......................................................................................................................................... ix
List of Figures ......................................................................................................................................... xiii

Chapter 1. INTRODUCTION .................................................................................................................. 1

Chapter 2. LITERATURE REVIEW ......................................................................................................... 4

2.1 Pasture Establishment by Direct Drilling ......................................................................................... 4

2.1.1 Pasture Establishment .................................................................................................................. 4
2.1.2 Direct Drilling ............................................................................................................................... 5
2.1.3 Development of pasture establishment techniques in New Zealand ......................................... 6
2.1.4 Tillage Effects on Soil Relative to Pasture Establishment .............................................................. 8
2.1.5 Soil Microenvironment Effects on Germination and Emergence of Pasture Species ............... 10

2.1.5.1 Opener Design Considerations ............................................................................................... 10
2.1.5.2 Influence of seed depth ........................................................................................................... 12
2.1.5.3 Temperature effects ............................................................................................................... 14

2.2 Plant relationships in Establishing Pasture ...................................................................................... 14

2.2.1 Effect of Seed Density .................................................................................................................. 15
2.2.2 Root Competition ......................................................................................................................... 18
2.2.3 Effect of Seed Size ....................................................................................................................... 20
2.2.4 Interspecific Competition ............................................................................................................ 21
2.2.5 Plant Arrangement ...................................................................................................................... 21
2.2.6 Grazing Management .................................................................................................................. 23
2.2.6.1 Defoliation .............................................................................................................................. 24
2.2.6.2 Animal Effects ......................................................................................................................... 26

2.3 Summary .......................................................................................................................................... 29

Chapter 3. METHODS AND MATERIALS .............................................................................................. 30

3.1 Introduction to Experimental Procedure .......................................................................................... 30
3.2 Description of Trial Site .................................................................................................................... 31
3.3 Experimental Design and Treatments ............................................................................................... 32
3.4 Fertiliser Policy, Weed Control and Irrigation ............................................................................... 38
3.5 Grazing Management ....................................................................................................................... 39
3.6 Sampling Procedure ........................................................................................................................ 41
Chapter 4 RESULTS AND DISCUSSION

Introduction .............................................................................. 48

4.1 Early Establishment .......................................................... 49
  4.1.1 Tall Fescue and Perennial Ryegrass Seedling Emergence and Population .... 49
    4.1.1.1 Introduction .................................................................. 49
    4.1.1.2 Results ........................................................................... 49
      4.1.1.2.1 Overall Species, Seeding Rate and Drill Method Effects .......... 49
      4.1.1.2.2 Effect of Position in the Cross Drill Treatment on Seedling
        Emergence and Population ...................................................... 51
      4.1.1.2.3 Effect of Seeding rate on Nominal Seeding Percentage Emergence ........ 52
      4.1.1.2.4 Population Achieved for Each Treatment .................................. 53
    4.1.1.3 Discussion ................................................................. 54
  4.1.2 Emergence and Population of Clover and Unsown Species ................. 61
    4.1.2.1 Results ......................................................................... 61
      4.1.2.1.1 Overall Species, Seeding rate and Drill Method Effects .......... 61
    4.1.2.2 Discussion .................................................................. 63
  4.1.3 Tiller ing Activity and Plant Leaf Number ..................................... 68
    4.1.3.1 Introduction .................................................................. 68
    4.1.3.2 Results .......................................................................... 70
      4.1.3.2.1 Overall Species, Seeding rate and Drill Method Effects .......... 70
      4.1.3.2.2 Interactive Effect of Species and Sowing Rate ...................... 72
      4.1.3.2.3 Effect of Plant Position ................................................. 73
      4.1.3.2.4 The Effect of Population .............................................. 75
      4.1.3.2.5 Interactions Between Drill Method and Seeding Rate for Fescue .... 77
    4.1.3.3 Discussion ................................................................. 80
  4.1.4 Treatment Effects on Seedling Weight, Extended Height and Plant Size
    Indices .................................................................................. 92
    4.1.4.1 Introduction .................................................................. 92
    4.1.4.2 Results ........................................................................... 93
      4.1.4.2.1 Treatment Effects on Seedling Weight .................................. 93
      4.1.4.2.1.1 Overall Effect of Species, Seeding Rate and Drill Methods .... 93
      4.1.4.2.1.2 Effect of Seeding Rate on Fescue and Ryegrass on Shoot Weight ..... 94
      4.1.4.2.1.3 Overall Effect of Species, Seeding Rate and Drill Method on Mean
        Relative Seeding Growth Rate .................................................. 94
      4.1.4.2.1.4 Effect of Population ................................................... 95
      4.1.4.2.1.5 Effect of In-row Population on Root Weight ..................... 98
      4.1.4.2.1.6 Effect of In-row Population on Other Plant Characteristics ... 99
    4.1.4.2.2 Treatment Effects on Extended Height and Plant Size Index ......... 100
      4.1.4.2.2.1 Overall Effect of Species Seeding Rate and Drill Method ...... 100
4.1.4.2.2 Interactive Effect of Species and Drill Method ........................................ 100
4.1.4.2.3 Interactive Effect of Species and Seeding Rate on Plant Size Distribution ... 101
4.1.4.2.4 Effect of Population ................................................................. 102
4.1.4.2.3 Drill Method and Seeding Rate Effects on Plant Size Characteristics ....... 103
4.1.4.3 Discussion ......................................................................................... 104
4.1.5 Herbage Composition and Mass ......................................................... 115
4.1.5.1 Introduction ...................................................................................... 115
4.1.5.2 Results ............................................................................................ 115
4.1.5.2.1 Seeding Rate and Drilling Method Effects on Ryegrass at 55 d.a.s. ....... 115
4.1.5.2.2 Overall Species, Seeding Rate and Drilling Method Effects at 150 d.a.s. 116
4.1.5.2.3 Interactive Effect of Species and Drilling Method ............................ 117
4.1.5.2.4 Interactive Effect of Seeding Rate and Drilling Method .................... 118
4.1.5.3 Discussion ......................................................................................... 119
4.1.6 Summary ........................................................................................... 129

4.2 Late Establishment .................................................................................. 131
4.2.1 Plant Size and Survival from 145 to 313 d.a.s. ........................................ 131
4.2.1.1 Introduction ...................................................................................... 131
4.2.1.2 Results ............................................................................................ 131
4.2.1.2.1 Tilling Activity ............................................................................ 131
4.2.1.2.1.1 Species Effects ........................................................................ 132
4.2.1.2.1.2 Overall Seeding Rate Effects .................................................. 133
4.2.1.2.1.3 Overall Drill Method and Position Effect ................................. 134
4.2.1.2.1.4 Drill Method Effect on Fescue and Ryegrass ......................... 135
4.2.1.2.1.5 Interactive Effect of Seeding Rate and Drill Method for Ryegrass . 136
4.2.1.2.1.6 Effect of In-row Population .................................................... 137
4.2.1.2.2 Leaf Number and Extended Height ............................................. 139
4.2.1.2.2.1 Interactive Effect of Drill Method and Species ....................... 139
4.2.1.2.3 Plant Survival .............................................................................. 143
4.2.1.2.3.1 Effect of Seeding Rate on Fescue and Ryegrass .................... 144
4.2.1.2.3.2 Effect of Drilling Method on Plant Survival ............................ 146
4.2.1.2.3.3 Effect of In-row Population .................................................... 148
4.2.1.3 Discussion ......................................................................................... 150
4.2.2 Herbage Botanical Composition and Mass from 145 to 314 d.a.s. ............ 169
4.2.2.1 Introduction ...................................................................................... 169
4.2.2.2 Results ............................................................................................ 169
4.2.2.2.1 Accumulation of Herbage Mass for a 40 day Period from August to October ................................................................. 169
4.2.2.2.2 Overall Species, Seeding Rate and Drilling Method Effects at 219 d.a.s. ................................................................. 170
4.2.2.2.3 Interactive Effect of Seeding Rate and Species on the Proportion of Unown Species ......................................................... 172
4.2.2.2.4 Overall Species, Seeding Rate and Drilling Method Effects at 278 d.a.s. ................................................................. 173
4.2.2.2.5 Effects of Urine Deposition ........................................................ 174
4.2.2.3 Discussion ......................................................................................... 175
4.2.3 Summary ........................................................................................... 180
4.2.4 Further Investigations ......................................................................... 182

4.3 Production Phase ................................................................................ 184
4.3.1 Herbage Composition, Mass and Accumulation ..................................... 184
4.3.1.1 Introduction ...................................................................................... 184
4.3.1.2 Results ............................................................................................ 184
4.3.1.2.1 Herbage Composition and Mass ................................................ 184
4.3.1.2.1.1 Effect of Species .................................................................... 184
4.3.1.2.1.2 Effect of Seeding Rate ............................................................ 188
4.3.1.2.1.3 Effect of Drilling Method ........................................................ 188
4.3.1.2.1.4 Interactive Effect of Species and Drilling Method ................. 189
Chapter 5. ROW SPACING, SEEDING RATE AND NITROGEN INTERACTIONS IN TALL FESCUE SWARDS ESTABLISHED BY DIRECT DRILLING ................................................................. 207

5.1 Introduction to Experimental Procedure ................................................................. 207

5.2 Methods and Materials .................................................................................................. 208

5.2.1 Description of Trial Site .......................................................................................... 208

5.2.2 Experimental Design and Treatments ................................................................. 209

5.2.3 Fertiliser Policy and Weed Control ......................................................................... 213

5.2.4 Grazing Management ............................................................................................... 213

5.2.5 Sampling Procedure ................................................................................................. 214

5.2.5.1 Emergence of Sown Grass Seed ......................................................................... 214

5.2.5.2 Clover and Weed Emergence .............................................................................. 214

5.2.5.3 Individual Seedling Weight ................................................................................ 215

5.2.5.4 Herbage Mass ...................................................................................................... 215

5.2.5.5 Botanical Composition ....................................................................................... 215

5.2.6 Statistical Analysis ................................................................................................. 215

5.3 Results and Discussion .................................................................................................. 217

5.3.1 Introduction ............................................................................................................ 217

5.3.2 Results ................................................................................................................... 217

5.3.2.1 Tall Fescue Seedling, Clover and Unsown Species Emergence and Population ................................................................. 217

5.3.2.1.1 Overall Nitrogen, Seeding Rate and Drill Method Effects ................................................. 217

5.3.2.1.2 Effect of Position in the Cross Drill Treatment on Population and Seedling Emergence ................................................................. 219

5.3.2.2 Seedling White Clover, Broadleaf Weed and Grass Weed Populations ................................................. 220

5.3.2.2.1 Overall Nitrogen, Seeding rate and Drill Method Effects ................................................. 220

5.3.2.3 Treatment Effects on Fescue Shoot Weight and Tiller Number and Weight ................................................. 221

5.3.2.3.1 Overall Nitrogen, Seeding rate and Drill Method Effects on Shoot Weight ................. 221

5.3.2.3.2 Overall Effect of Nitrogen, Seeding Rate and Drill Method on Mean Relative Seedling Growth Rate ................................................................................. 223

5.3.2.3.4 Overall Nitrogen, Seeding Rate and Drill Method Effects on Tiller Number and Weight ................................................................................. 224

5.3.2.3.5 Effect of Plant Position on Tiller Weight and Number .................................................................................. 225

5.3.2.3.6 Interactive Effect of Seeding Rate and Drill Method on Tiller Weight and Number .......... 225

5.3.2.3.7 Effect of In-row Population on Seedling and Tiller Weight .................................................................................. 226

5.3.2.4 Treatment Effects on Herbage Composition and Mass ................................................................................. 227

5.3.2.4.1 Overall Nitrogen, Seeding Rate and Drill Method Effects at 154 d.a.s. ................. 227

5.3.2.4.2 Effect of Drill Method on Unsown Species at 154 d.a.s. ................................................. 228

5.3.2.4.3 Overall Nitrogen, Seeding Rate and Drill Method Effects at 213 d.a.s. ................. 229

5.3.2.4.4 Overall Nitrogen, Seeding Rate and Drill Method Effects at 249 d.a.s. ................. 230

5.4 Discussion .................................................................................................................. 231

5.5 Summary .................................................................................................................. 240
Chapter 6. CONCLUSION ..................................................................................................... 241

6.1 The Major Conclusions From This Project Are: ............................................................ 241
  6.1.1 Drilling Pattern ........................................................................................................ 241
  6.1.2 Row Spacing ........................................................................................................... 241
  6.1.3 Drill Design ............................................................................................................. 241
  6.1.4 Clover Emergence .................................................................................................. 242
  6.1.5 Seeding Rates ........................................................................................................ 242
  6.1.6 Tiller Population .................................................................................................... 242
  6.1.7 Nitrogen Application ............................................................................................. 243
  6.1.8 Species Performance ............................................................................................. 243

6.2 Future Work ................................................................................................................. 243

REFERENCES .................................................................................................................. 245

PERSONAL COMMUNICATION ......................................................................................... 276

Appendices

  Appendix One .................................................................................................................. A1-1
  Appendix Two ................................................................................................................. A2-1
  Appendix Three .............................................................................................................. A3-1
  Appendix Four ............................................................................................................... A4-1
LIST OF TABLES

Table 3.3.1 Target Seeding Rate and Seeding Rate Achieved for Fescue and Ryegrass ....37
Table 3.5.1 Schedule for Grazing and Topping ..........................................................40
Table 4.1.1.1 Effects of Species, Seeding Rate and Drilling Method on Percentage Emergence and Population at 42 Days After Sowing .............................................50
Table 4.1.1.2 Effect of Seeding Rate and Position (Within the Cross Drill Treatment) on Nominal Seedling Emergence Percentage .........................................................52
Table 4.1.1.3 Effect of Seeding rate on Nominal Percentage Emergence ......................53
Table 4.1.1.4 Comparison of Plant Populations of Fescue and Ryegrass 42 d.a.s. in Order of Increasing Plant Density .................................................................53
Table 4.1.2.1 Effect of Species, Seeding Rate and Drill Method on Population of White Clover and Unsown Species Seedlings 37 d.a.s..........................................................62
Table 4.1.3.1 Effect of Species, Sowing Rate and Drill Method on the Number of Leaves per Plant at 26 d.a.s., and the Number of Tillers per Plant and Skewness of Tiller Number and T X L index at 43 and 145 d.a.s. ........................................71
Table 4.1.3.2 Effect of Seeding rate on the Skewness Coefficient of Tiller and Leaf Number and Plant Tiller by Leaf Size Index for Ryegrass and Fescue at 43 and 145 d.a.s.................................................................72
Table 4.1.3.3 Effect of Position on the Number of Tillers, Distribution of Tiller Number and of Tiller by Leaf Index (Combined Species) ..........................................................74
Table 4.1.3.4 Effect of In-row Population on Tiller Number and Skewness of Tiller Number and Tiller X Leaf Index for both Fescue and Ryegrass. ........................................75
Table 4.1.3.5 Effect of Drill Method on Tiller and Leaf Number at High and Low Seeding Rate at 43 d.a.s. for Fescue and Ryegrass .........................................................78
Table 4.1.3.6 Effect of Species, Seeding Rate and Drill Method on Tiller Weight up to 135 Days After Sowing (mg/tiller) .................................................................79
Table 4.1.3.7 Effect of Seeding Rate and Drilling Method on Fescue and Ryegrass Tiller Weight at 49 and 135 d.a.s. (mg/tiller) .................................................................79
Table 4.1.3.8 Variation in Distance Between Ryegrass Seedlings Along A Row .............84
Table 4.1.4.1 Effect of Species, Seeding Rate and Drill Method on Shoot Weight up to 135 Days After Sowing (mg/plant) .................................................................93
Table 4.1.4.2 Effect of Seeding Rate on Fescue and Ryegrass Shoot Weight (mg/plant) ....94
Table 4.1.4.3 Effect of Species, Drill Method and Seeding Rate on the Mean Relative Growth Rate of Fescue and Ryegrass up to 135 Days After Sowing ([mg mg^{-1} day^{-1}]95
Table 4.1.4.4 Effect of In-row Population on Root Weight, Tiller number, Main roots and Daughter Roots at 54 d.a.s. .................................................................99
Table 4.1.4.5  Effect of Species and Seeding Rate on Extended Height and Skewness of
Extended Height and Leaf by Extended Height Index at 26, 43 and 145 d.a.s.100

Table 4.1.4.6  Effect of Drill Method on Extended height of Fescue and Ryegrass Plants....101

Table 4.1.4.7  Effect of Seeding rate on Skewness of Extended Height and Leaf by Extended
Height Index for Ryegrass and Fescue at 43 and 145 d.a.s. .............................102

Table 4.1.4.8  Effect of In-row Population on Extended Height and Skewness of Extended
Height and Leaf X Extended Height Index for both Fescue and Ryegrass. ....103

Table 4.1.4.9  Effect of Drill Method on Tiller and Leaf Number at 145 d.a.s. and Shoot and
Tiller Weight at 135 d.a.s. at High and Low Seeding Rate (Combined Species
Results) .............................................................................................................104

Table 4.1.5.1  Effect of Drill Method and Seeding Rate on the Herbage Composition and
Mass of Ryegrass at 55 d.a.s. (6-6-90) ...............................................................116

Table 4.1.5.2  Effect of Species, Seeding Rate and Drill Method on the Herbage Composition
and Mass at 150 d.a.s. (9-9-90) ........................................................................117

Table 4.1.5.3  Effect of Drill Method on Herbage Composition and Mass of Fescue and
Ryegrass 150 d.a.s. (9-9-90) .............................................................................118

Table 4.1.5.5  Effect of Drill Method on Fescue and Ryegrass Shoot Weight, Tiller Weight
and Extended Height and Mass at 135 d.a.s. ..................................................128

Table 4.2.1.1  Time and Level of Probability for Main Treatment Effects on Tiller Number
per Plant for Combined Species and for Fescue and Ryegrass from 178 to 313
d.a.s .....................................................................................................................132

Table 4.2.1.2  Effect of In-row Population on Tiller Number of Fescue and Ryegrass Plants.138

Table 4.2.1.3  Time and Level of Probability for Main Treatment Effects and Interactions
Between Main Treatments on Leaf Number and Extended Height for Combined
Species and for Fescue and for Ryegrass from 178 to 244 d.a.s. .....................140

Table 4.2.1.4  Effect of Drill Method on Leaf Number of Fescue and Ryegrass Plants ....141

Table 4.2.1.5  Effect of Drill Method on Extended Height of Fescue and Ryegrass Plants...142

Table 4.2.1.6  Number, Timing and Cause of Loss of Tagged Ryegrass and Fescue Plants..144

Table 4.2.1.7  Effect of Drilling Method on the Percentage of Plants Remaining ............147

Table 4.2.1.8  Effect of Position on the Skewness of Tiller Number ...............................147

Table 4.2.1.9  Effect of In-row Population on the Skewness of Tiller Number in Fescue and
Ryegrass ..............................................................................................................148

Table 4.2.2.1  Effect of Species, Seeding Rate and Drill Method on Accumulation of Herbage
Mass for a 40 day Period in the First Spring After Sowing.................................170

Table 4.2.2.2  Effect of Drilling Method on Accumulation of Herbage Mass of Fescue and
Ryegrass for a 40 day Period in the First Spring After Sowing .........................170
Table 4.2.2.3 Effect of Species, Seeding Rate and Drill Method on the Herbage Composition and Mass at 219 d.a.s. (21-11-90) .................................................. 171

Table 4.2.2.4 Effect of Seeding Rate on Herbage Composition and Mass in Fescue and Ryegrass at 219 d.a.s. (21/11/90) .................................................. 172

Table 4.2.2.5 Effect of Species, Seeding Rate and Drill Method on the Herbage Composition and Mass at 278 d.a.s. (20-1-91) .................................................. 173

Table 4.2.2.6 Effect of Urine Deposition on Herbage Mass and Composition of Fescue and Ryegrass at 182 d.a.s. .................................................. 175

Table 4.3.1.1 Effect of Species on the Mass of Sown Species, Clover, Unsown Species and Total Live Herbage at 393, 496, 576 and 684 d.a.s. ......................... 187

Table 4.3.1.2 Effect of Seeding Rate on the Mass of Sown Species for Fescue and Ryegrass at 393, 496, 576 and 684 d.a.s. (kgDM ha-1) ................. 188

Table 4.3.1.3 Effect of Drilling Method on the Mass of Sown Species for Fescue and Ryegrass at 393, 496, 576 and 684 d.a.s. (kgDM ha-1) ................. 189

Table 4.3.1.4 Effect of Drill Method on the Mass of Sown Species and Total Live Herbage for Fescue and Ryegrass at 393 d.a.s. (kgDM ha-1) ................. 190

Table 4.3.1.5 Proportion of Volunteer Ryegrass in the Live Herbage of the Fescue Sward from November 1990 to March 1992 (219 to 684 d.a.s.) ......................... 190

Table 4.3.1.6 Effect of Species, Seeding Rate and Drilling Method on Accumulated Herbage Mass (kgDM ha-1) During the Production Phase (246 to 625 d.a.s.) ............... 192

Table 4.3.1.7 Effect of Drill Method on Herbage Mass Accumulated in Fescue and Ryegrass During the Production Phase (kgDM ha-1) ................. 194

Table 4.3.1.8 Effect of Drill Method on Average Pre- and Post-graze Herbage Mass (kgDM ha-1) for Period One of the Production Phase for Fescue and Ryegrass (246-393 d.a.s.) .................................................. 195

Table 4.3.1.9 Effect of Drill Method on Average Pre- and Post-graze Herbage Mass (kgDM ha-1) for the Entire Production Phase for Fescue and Ryegrass (246-625 d.a.s.) .................................................. 196

Table 5.2.1 Target Seeding Rate and Seeding Rate Achieved for Fescue ......................... 212

Table 5.2.2 Schedule for Grazing and Topping .................................................. 214

Table 5.3.2.1 Effects of Nitrogen, Seeding Rate and Drilling Method on Population of Seedlings at 45, 53, 67 and 87 d.a.s. and on Percentage Emergence at 53 d.a.s. 218

Table 5.3.2.2 Effect of Position (Within the Cross Drill Treatment) on Population of Seedlings at 45, 53, 67 and 87 d.a.s. and on Percentage Emergence at 53 d.a.s. 219

Table 5.3.2.3 Effect of Seeding Rate and Drill Method on Population of White Clover and Unsown Species Seedlings at 49 d.a.s. (22/6/91) ......................... 221

Table 5.3.2.4 Effect of Nitrogen, Seeding Rate and Drill Method on Shoot Weight at 53, 67 and 87 Days After Sowing (mg/plant) .................................................. 222
Table 5.3.2.5 Effect of Nitrogen, Drill Method and Seeding Rate on the Mean Relative Growth Rate of Fescue and Ryegrass up to 87 Days After Sowing ([mg mg-1] day-1) ............................................................223

Table 5.3.2.6 Effect of Nitrogen, Seeding Rate and Drill Method on Tiller Number m row-1 and m-2, Tiller Weight and Weight of Tillers m-2 at 121 Days After Sowing224

Table 5.3.2.7 Effect of Position on Tiller Number m row-1 and m-2, Tiller Weight and Weight of Tillers m-2 in the Cross-drilled Treatment at 121 Days After Sowing225

Table 5.3.2.8 Interactive Effect of Seeding Rate and Drill Method on Tiller Number m row-1 and m-2, Tiller Weight and Weight of Tillers m-2 at 121 Days After Sowing226

Table 5.3.2.9 Effect on In-row Population on Tiller Weight at 121 d.a.s........................................227

Table 5.3.2.10 Effect of Nitrogen, Drill Method and Seeding Rate on the Herbage Composition and Mass at 154 d.a.s. (7-10-91) ...............................................................228

Table 5.3.2.11 Effect of Drill Method on the Mass of Giant Buttercup, Toad Rush, Other Broadleaf Weed Species and Other Unsown Grass Species at 154 d.a.s. (7-10-91) ..................................................................................................................229

Table 5.3.2.12 Effect of Nitrogen, Drill Method and Seeding Rate on the Herbage Composition and Mass at 213 d.a.s. (6-12-91) .................................................................230
LIST OF FIGURES

Figure 3.3.1 Layout Of Trial Plots (Not To Scale) With Main Plots Differentiated By Double Lines And Sub-Plots By Single Lines .................................................. 34

Figure 3.3.2 Trial Paddock ............................................................................. 38

Figure 3.6.1 Diagram of the Three Possible Seed Positions in the Cross Drill Treatment .... 42

Figure 3.6.2 The Template Used for Emergence Counts of the Cross Drilled Plots .......... 42

Figure 4.1.3.2 Change in In-row Population Required for a 25 % Change in the Number of Tillers/plant ................................................................. 76

Figure 4.1.4.1 Effect of In-row Plant Population on Ryegrass and Fescue Shoot Weight. .... 97

Figure 4.1.4.2 Effect of In-row Population on Root Weight of Ryegrass at 54 Days After Sowing .................................................................................. 98

Figure 4.1.5.1 Effect of Drilling Method at Two Seeding Rates on Mass of Unsown Species at 150 d.a.s ................................................................. 119

Figure 4.1.5.2 Effect of Drilling Method at Two Seeding Rates on Live Herbage Mass at 150 d.a.s ...................................................................................... 119

Figure 4.1.5.3 The First Grazing of Ryegrass (55 d.a.s., 6-6-90) .................................. 120

Figure 4.1.5.4 Whole Trial Grazing 150 d.a.s. (9-9-90) ........................................ 121

Figure 4.2.1.1 Effect of Species on Tiller Number per Plant .................................. 133

Figure 4.2.1.2 Effect of Seeding Rate on Tiller Number per Plant ................................ 134

Figure 4.2.1.3 Effect of Position on the Tiller Number of Plants Sown by Cross-drilling .... 135

Figure 4.2.1.4 Effect of Drilling Method on Tiller Number for Fescue and Ryegrass Plants 136

Figure 4.2.1.5 Effect of Drill Method at High and Low Seeding Rate on Tillers per Plant in Fescue at 313 d.a.s ................................................................. 137

Figure 4.2.1.6 Effect of Drill Method at High and Low Seeding Rate on Tillers per Plant in Ryegrass at 313 d.a.s ................................................................. 137

Figure 4.2.1.7 Change in In-row population Required for a 25 % Change in the Number of Tillers per plant ................................................................. 139

Figure 4.2.1.8 Effect of Seeding Rate on the Percentage of Remaining Plants and Skewness Coefficient for Fescue and Ryegrass ........................................ 146

Figure 4.2.1.9 Trial Area Just Prior to the Grazing Which Occurred at 219 d.a.s. (November), Showing Seedhead Development in Ryegrass on the Right with Fescue on the Left ......................................................... 151

Figure 4.3.1.1 Composition of Live Fescue Herbage for the Trial Period .................. 185
Figure 4.3.1.2 Composition of Live Ryegrass Herbage for the Trial Period ...............185

Figure 4.3.1.3 Effect of Species on Pre- and Post-grazing Herbage Mass from 246 to 625 d.a.s. 193

Figure 5.2.1 Layout of Trial plots (not to scale) with Main Plots Differentiated by Double Lines .................................................................................................................................................. 211

Figure 5.2.2 Trial Paddock at 126 d.a.s. (12/9/91) ................................................................................................................. 213