

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.

AN X-RAY TECHNIQUE FOR DETERMINING SEED

PLACEMENT IN DIRECT DRILLED SOILS

A thesis presented in partial fulfilment  
of the requirements for the degree of  
Master of Philosophy at  
Massey University

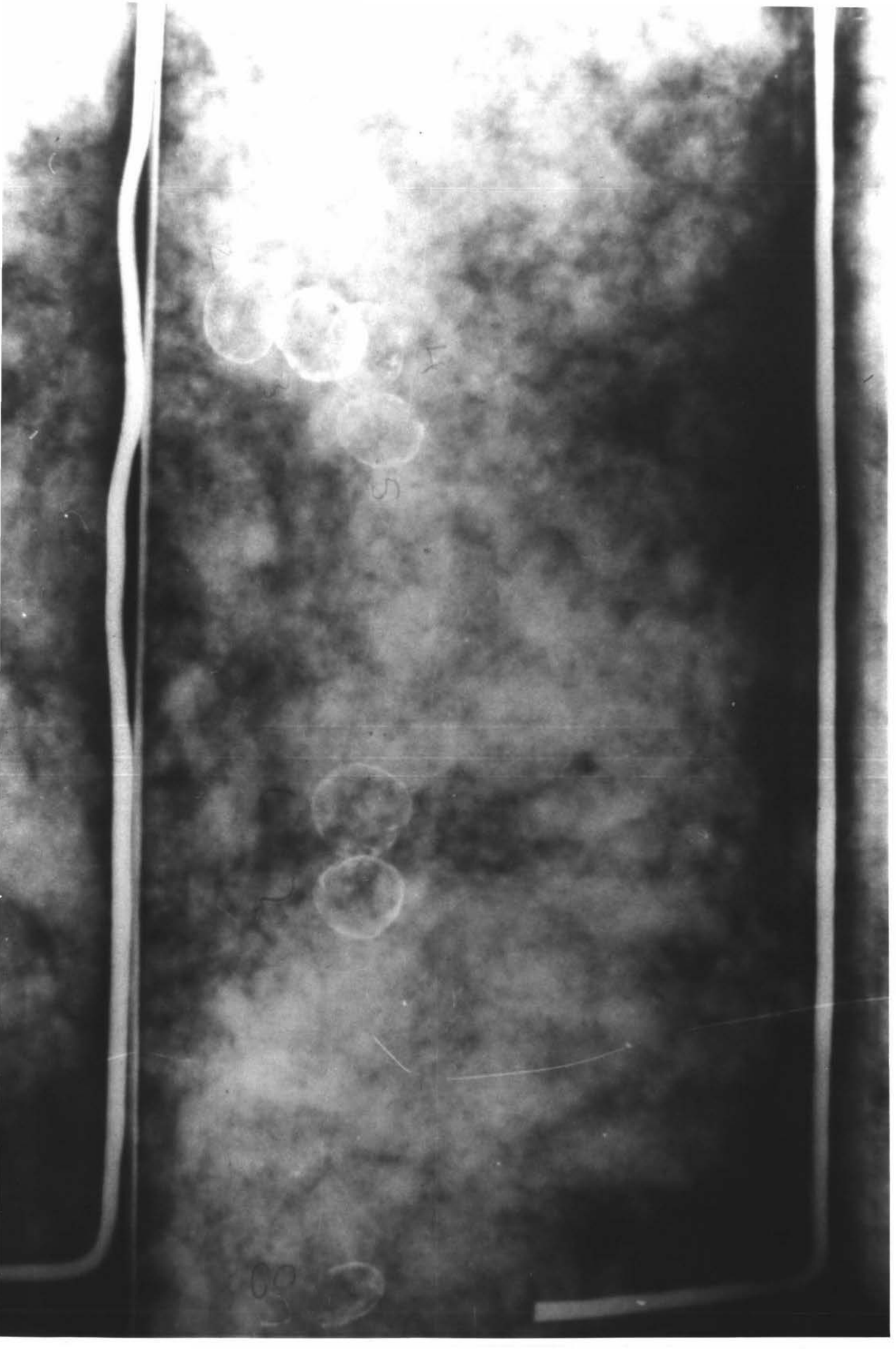
ALLAN JOSEPH CAMPBELL

1985

## TABLE OF CONTENTS

|  |        |
|--|--------|
| ABSTRACT.....  | (i)    |
| LIST OF TABLES.....  | (iii)  |
| LIST OF FIGURES.....   | (v)    |
| LIST OF APPENDICES.....  | (vii)  |
| ACKNOWLEDGEMENTS.....  | (viii) |
| <br>   |        |
| 1. INTRODUCTION.....   | 1      |
| <br>   |        |
| 2. LITERATURE REVIEW   |        |
| 2.1 INTRODUCTION.....  | 2      |
| 2.2 BIOLOGICAL PERFORMANCE OF DIRECT DRILLING<br>OPENERS.....  | 2      |
| 2.2.1 Soil moisture.....   | 3      |
| 2.2.2 Soil temperature.....  | 4      |
| 2.2.3 Mechanical impedance.....  | 5      |
| 2.2.4 Aeration.....  | 6      |
| 2.3 DIRECT DRILLING OPENER ASSEMBLIES.....   | 7      |
| 2.3.1 Description of opener components.....  | 8      |
| 2.3.2 Opener assemblies.....   | 9      |
| 2.4 SEED PLACEMENT BY DRILLING OPENERS.....  | 11     |
| 2.4.1 Agronomy of in-row spacing.....  | 11     |
| 2.4.2 Agronomy of depth of seed placement.....   | 13     |
| 2.4.3 Mechanics of seed depth placement.....   | 15     |
| 2.4.4 Methods of determining seeding depth.....  | 18     |
| <br>   |        |
| 3. DEVELOPMENT OF AN X-RAY TECHNIQUE   |        |
| 3.1 INTRODUCTION.....  | 20     |
| 3.2 EXPERIMENTAL APPROACH.....   | 21     |
| 3.3 X-RAY IMAGE DISTORTION: PROBLEM AND SOLUTIONS.....   | 22     |
| 3.3.1 Possible solutions.....  | 22     |
| 3.3.2 Distortion correction technique.....   | 24     |
| 3.4 DEVELOPMENT OF SEED COATING PROCEDURES.....  | 30     |
| 3.4.1 Liquid coatings.....   | 30     |
| 3.4.2 Powdered coatings.....   | 30     |
| 3.5 EVALUATION OF TYPE AND AMOUNT OF COATING.....  | 34     |
| 3.5.1 Experiment 1. Effects of coating types and<br>amounts on the clarity of X-ray images.....  | 35     |
| 3.5.2 Experiment 2. Evaluation of powdered seed<br>coatings at low rates ( 50%).....   | 43     |
| 3.5.3 Experiment 3. Evaluation of red lead oxide<br>coating levels on a small round seed (rape)<br>( <i>Brassica campestris</i> )..... | 45     |
| 3.5.4 Discussion of Experiments 1,2 and 3.....   | 47     |
| 3.6 EVALUATION OF THE EFFECT OF SOIL ON X-RAY IMAGE<br>CLARITY.....  | 49     |
| 3.6.1 Experiment 4. Evaluation of the effects of<br>soil thickness on the clarity of X-ray image....                                   | 50     |
| 3.6.2 Experiment 5. Evaluation of the effects of<br>soil type and soil moisture content on X-ray<br>image clarity.....                 | 53     |
| 3.7 EFFECT OF COATING LEVELS OF RED LEAD OXIDE AND<br>RADIATION ON SEED GERMINATION (EXPERIMENTS 6, 7<br>AND 8).....                   | 57     |

|       |   |     |
|-------|---|-----|
| 3.8   | EVALUATION OF SEED IN-SOIL ELAPSED TIME ON THE CLARITY OF X-RAY IMAGES AND SEED IMAGE MOVEMENT (EXPERIMENT 9, 10 AND 11)..... | 63  |
| 3.9   | DEVELOPMENT OF EQUIPMENT FOR FIELD SAMPLING AND SUBSEQUENT X-RAYING.....  | 74  |
| 3.9.1 | Development of a soil block cutting machine.....  | 75  |
| 3.9.2 | Development of the soil block bins.....   | 78  |
| 3.9.3 | Holding jig for X-raying soil blocks.....   | 80  |
| 3.9.4 | Field sampling procedures.....  | 82  |
| 3.10  | SUMMARY OF THE X-RAY TECHNIQUE.....   | 86  |
| 4.    | FIELD EVALUATION OF THE X-RAY TECHNIQUE   |     |
| 4.1   | OBJECTIVES.....   | 89  |
| 4.2   | MATERIALS AND METHODS.....  | 89  |
| 4.2.1 | Site selection and preparation.....   | 89  |
| 4.2.2 | Selection of variables.....   | 89  |
| 4.2.3 | Field measurements.....   | 98  |
| 4.2.4 | Sampling times.....   | 99  |
| 4.2.5 | Limiting conditions.....  | 100 |
| 4.3   | RESULTS AND DISCUSSION.....   | 102 |
| 4.3.1 | Barley experiment.....  | 102 |
| 4.3.2 | Lupin experiment.....   | 114 |
| 4.4   | DISCUSSION OF THE FIELD EXPERIMENTS.....  | 120 |
| 4.4.1 | X-ray technique.....  | 120 |
| 4.4.2 | Opener performance.....   | 121 |
| 5.    | SUMMARY AND CONCLUSIONS.....  | 126 |
| 6.    | BIBLIOGRAPHY.....   | 130 |
| 7.    | PERSONAL COMMUNICATIONS.....  | 136 |
| 8.    | APPENDICES.....   | 137 |



## ABSTRACT

The objectives of this study were to develop and document a reliable workable X-ray technique for identifying seed placement in the soil; to examine those factors which might influence this procedure and to demonstrate the use of the technique in a field experiment.

The X-ray technique was based on the principle that seeds coated with a heavy metal powder, when X-rayed within a soil mass, appeared on the X-ray film as white or grey images on a dark background.

A coating procedure (based on commercial pelleting) was developed to apply the heavy metal powder to the seed. As the seed images on the X-ray film were to be a shadow representation of the actual seed position in the soil mass, a correction procedure to locate the true positions of the seed was developed.

A series of laboratory experiments confirmed that red lead oxide was the most suitable coating material and that higher intensities of coating were required as seed size decreased. Neither soil type nor soil moisture content appeared to have a marked affect on the clarity of the X-ray images. Seed germination was not affected by the amount of red lead oxide coating, the coating procedure, or exposure to moderate levels of radiation.

Soil blocks measuring 75 mm by 75 mm by 240 mm long containing the coated seeds should be taken as soon as possible after sowing, as image clarity diminished over time and seed movement occurred in the case of seeds with epigeal germination.

Equipment developed to assist in field sampling included a soil-block-cutter, re-useable sample bins and a holding jig for X-raying the soil blocks in their bins.

Thus the X-ray technique had the ability to determine three dimensional seed placement within a soil mass (sowing depth, in-row width and in-row spacing). The ability of the X-ray technique offers new possibilities for explaining those factors which affect seed placement by direct drilling equipment in field situations.

## LIST OF TABLES

|              |  |    |
|--------------|--|----|
| Table 2.2    | Factors which affect the rate of germination (Gordon, 1973).....                                   | 2  |
| Table 2.3.1  | Description of direct drilling opener types.....   | 8  |
| Table 2.4.2  | Effect of planting depth on barley performance (Evans, 1978b).....                                 | 14 |
| Table 3.2    | Possible factors affecting X-ray technique for locating seeds in soil.....                         | 21 |
| Table 3.5.1a | Effect of chemical seed coating type on X-ray image intensity.....                                 | 40 |
| Table 3.5.1b | Effect of amounts of chemical seed coating on the intensity of the X-ray image.....                | 40 |
| Table 3.5.1c | Effect of seed type and chemical seed coating type on X-ray image intensity.....                   | 41 |
| Table 3.5.2a | Effect of chemical seed coating type and amount on X-ray image intensity.....                      | 43 |
| Table 3.5.2b | Effect of seed type and chemical seed coating type on X-ray image intensity.....                   | 44 |
| Table 3.5.3a | Effect of red lead oxide coating on the intensity of the rape seed X-ray images.....               | 45 |
| Table 3.6.1a | X-ray settings for soil thicknesses.....   | 51 |
| Table 3.6.1b | Effect of soil thickness on the clarity of the X-ray images.....                                   | 52 |
| Table 3.6.1c | Effect of seed type on the clarity of the X-ray images.....  | 52 |
| Table 3.6.2a | Effect of soil type on the clarity of the X-ray images.....  | 54 |
| Table 3.6.2b | Effect of soil moisture content on the clarity of the X-ray image.....                             | 55 |
| Table 3.7a   | Effect of red lead oxide coating on percent germination.....                                       | 58 |
| Table 3.7b   | Effect of radiation on seed percent germination....  | 59 |
| Table 3.8a   | Relative seed positions in the soil as related to day one.....                                     | 67 |
| Table 3.8b   | Values for seed depth as determined by the X-ray technique and the seedling tracing technique..... | 70 |



|              |  |     |
|--------------|--|-----|
| Table 4.2.2  | Factors though likly to affect opener performance in the field.....  | 91  |
| Table 4.3.1a | Effect of forward speed on average sowing depth, standard error of sowing depth, standard error of sowing width and percent seedling emergence of direct drilled barley..... | 102 |
| Table 4.3.1b | Estimated percent seedling emergence as effected by forward speed determined by the covariate analyses in direct drilled barley...   | 103 |
| Table 4.3.1c | Effect of opener type on average sowing depth, standard error of sowing depth, standard error of sowing width and percent seedling emergence of direct drilled barley.....   | 106 |
| Table 4.3.1d | Estimated percent seedling emergence as effected by opener type determined by covariate analyses in direct drilled barley.....   | 108 |
| Table 4.3.1e | A comparision of the variances for the opener factor as computed for the original analysis and the subsequent corvariate analyses.....                                       | 109 |
| Table 4.3.1f | Effect of opener type and forward speed on percent seedling emergence of direct drilled barley.....  | 111 |
| Table 4.3.1g | Effect of opener type and forward speed on the estimated percent seedling emergence based on covariate analyses of direct drilled barley.....                                | 112 |
| Table 4.3.2a | Effect of forward speed on average sowing depth, standard error of sowing depth, standard error of sowing width and percent seedling emergence of direct drilled lupin.....  | 114 |
| Table 4.3.2b | Effects of opener type on average sowing depth, standard error of sowing depth, standard error of sowing width and percent seedling emergence of direct drilled lupin.....   | 117 |

## LIST OF FIGURES

|               |  |    |
|---------------|--|----|
| Figure 3.3    | Three dimensional representation of the X-ray distortion problem.....                        | 23 |
| Figure 3.3.2a | Principles involved in using the X-ray stereo technique for determining the Z component..... | 26 |
| Figure 3.3.2b | Three dimensional representation of the correction procedure for the X-ray technique.....    | 28 |
| Figure 3.4.2  | Seed coating apparatus.....  | 31 |
| Figure 3.5.1a | Coated seeds for X-raying on a 20.0 mm X 20.0 mm square grid.....                            | 38 |
| Figure 3.5.1b | Computer output of microdensitometer reading.....  | 39 |
| Figure 3.5.4  | Plot of image intensity versus red lead oxide coatings.....                                  | 48 |
| Figure 3.7a   | Soybean germination.....   | 60 |
| Figure 3.7b   | Barley germination.....  | 61 |
| Figure 3.7c   | Rape seed germination.....   | 62 |
| Figure 3.8a   | Seedling emergence blocks.....   | 66 |
| Figure 3.8b   | Curves of lupin seed position in the soil as time progressed.....                            | 68 |
| Figure 3.8c   | Curves of barley seed position in the soil as time progressed.....                           | 69 |
| Figure 3.8d   | Curves of rape seed position in the soil as time progressed.....                             | 71 |
| Figure 3.8e   | Radiograph of 2 soil blocks showing differences in soil density.....                         | 73 |
| Figure 3.9.1  | Soil block cutting machine.....  | 76 |
| Figure 3.9.2  | Aluminium soil block sample bin.....   | 79 |
| Figure 3.9.3  | Soil block positioning jig.....  | 81 |
| Figure 3.9.4  | X-ray grid for measuring image positions (on light table).....                               | 85 |
| Figure 4.2.1a | Layout of plots in the field experiment 1, 2 and 3 locations of replications.....            | 90 |
| Figure 4.2.2a | Hoe opener assembly.....   | 92 |
| Figure 4.2.2b | 2000 winged opener assembly.....   | 93 |

|   |     |
|---|-----|
| Figure 4.2.2c Triple disc opener assembly.....  | 94  |
| Figure 4.2.2d 1000 winged opener assembly.....  | 95  |
| Figure 4.2.2e Test rig with a single opener and cone<br>seeder assembly.....                  | 97  |
| Figure 4.3.1a Effects of forward speed on seedling emergence<br>of direct drilled barley..... | 104 |
| Figure 4.3.1b Effects of opener type on seedling emergence<br>of direct drilled barley.....   | 110 |
| Figure 4.3.2a Effects of forward speed on seedling emergence<br>of direct drilled lupins..... | 116 |
| Figure 4.3.2b Effects of opener type on seedling emergence<br>of direct drilled lupins.....   | 119 |

## LIST OF APPENDICES

|              |   |     |
|--------------|---|-----|
| Appendix 1:  | Computer program to caluate the average depth, average width, and average in-row spacing along with the standard error of each for each soil block taken..... | 137 |
| Appendix 2:  | Computer program to convert the microdensitometer values from numbers to letters.....   | 139 |
| Appendix 3:  | Computer program to locate the seed and caluate the average image intensity of each seed from the microdensitometer output file.....                          | 141 |
| Appendix 4:  | Intensity values for coated soybean and barley seed (complete data).....  | 142 |
| Appendix 5:  | Intensity values for powder coated soybean and barley using low coating levels (complete data).....   | 143 |
| Appendix 6:  | Intensity values for red lead oxide coated rape seed (complete data).....   | 144 |
| Appendix 7:  | Image clarity rating for three seed types and four soil thicknesses (complete data).....  | 145 |
| Appendix 8:  | Image clarity ratings (1 minimun clarity, 15 maximun clarity) for each of three seed types in five soils at three moisture conditions (complete data).....    | 146 |
| Appendix 9:  | Percent germination for each seed type as affected by amount of seed coating and X-ray radiation (complete data).....   | 148 |
| Appendix 10: | Seed positions relative to day one in the soil as given by the X-ray technique for soft and hard soil bases.....  | 149 |
| Appendix 11: | Definitions of factors possibly affecting seed placement in the soil.....   | 150 |
| Appendix 12: | Values for average sowing depth, standard error of depth, standard error of width and percent emergence for direct drilled barley (complete data).....        | 151 |
| Appendix 13: | Values for average sowing depth, standard error of depth, standard error of width and percent emergence for direct drilled lupins (complete data).....        | 153 |

## ACKNOWLEDGEMENTS

I wish to express my thanks to the following individuals, groups and firms for their assistance in undertaking this work.

To Dr. John Baker as my supervisor who provided the idea and supported this work with many hours of discussion, criticism and expertise in the area of seed placement in direct drilled soils.

To Dr. Ashraf Choudhary as my co-supervisor for his valuable consultations on direct drilling seed placement and his time and patience in reviewing the early drafts of this work.

To Agricultural Canada in particular my Director Dr. L.B. MacLeod and my Section Head Dr. John MacLeod for their support and assistance in undertaking this educational sabbatical.

To the Veterinary Clinical Science Department, Massey University in particular Dr. M.W. O'Callaghan and K.C. Caro for their valuable expertise and the extensive use of the X-ray equipment during the course of this project.

To the Chemistry Department, Massey University and in particular Mr. Brian Anderson for his instruction and the use of equipment and computer programs in the department.

To the Seed Technology Centre, Massey University for their instruction and the use of the facilities for the seed testing aspects of the project.

To the staff of the Agronomy Department, Massey University in particular the technicians who were always available to provide expertise on technical matters pertaining to this work.

To Hodder and Tolley Ltd. Seed Coating Division and the Manager Mr. Moris Suckling for consultations on the processes involved in the seed coating procedures.

To Mr. Greg Arnold for his hours of discussion on the special statistical problems created by this type of study.

To friends in both New Zealand and Canada for their support and understanding, particularly William, Mary and Christopher Ritchie in New Zealand and to Mr. Lloyd Kerry for the very capable way he carried on work and looked after my affairs in Canada during my absence.

Finally to my wife Dr. Catherine Noseworthy for her support, encouragement and understanding through the long hours involved in this work.

## 1. INTRODUCTION

The general practice in crop production has been to till the soil to prepare a uniform level seedbed into which seeds were placed (Loveday, 1980). Increases in tractor fuel and labor costs, together with decreases in available labor, recognition of the need for erosion control and the development of modern herbicides have all lead to a reduction in cultivation and the concept of no-tillage or direct drilling (Allen, 1981; Dickey and Rider, 1980). Erbach (1980) described the difference between no-till and cultivated seedbed conditions. According to Erbach, in using conventional tillage the soil was worked to produce a smooth, level and uniform seedbed. In direct drilling, residues were either absent or left on the undisturbed soil prior to planting. As a result, direct drilling openers were forced to operate in a different soil environment compared with conventional seed drills.

Early work in developing direct drilling openers entailed using or modifying conventional openers (Allen, 1981; Erbach, 1980). This practice met with only limited success due to the harder nature of the direct drilling seedbed. Early modifications to direct drilling openers concentrated on improving the mechanical performance (Allen 1981, Erbach 1980). As mechanical performance improved, hitherto unidentified problems associated with biological performance became apparent (Baker, 1976; Erbach, 1980). One area which affected both mechanical performance and biological performance was the depth at which the seed was placed in the soil.

In an attempt to accurately determine seeding depth, Barr (1981) put forward an idea for coating seeds with a heavy metal coating and determining seed placement by removing soil samples and X-raying them to locate the position of the seeds in the soil.

The objectives of this project were: 1. To develop and refine the X-ray technique so that it could form a reliable and workable technique for determining seed placement by direct drilling openers in the field; and 2. to demonstrate the ability of the X-ray technique in evaluating seed placement by selected direct drilling openers in a field experiment.