

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.

THE REQUIREMENTS OF DRY FERTILIZER PLACEMENT
IN DIRECT DRILLED CROPS BY IMPROVED CHISEL

COULTER

A THESIS PRESENTED IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE
OF

MASTER OF PHILOSOPHY IN
AGRICULTURAL MECHANISATION AT
MASSEY UNIVERSITY, PALMERSTON NORTH

BY

CHOUdry MUHAMMAD AFZAL
1981

CHAPTER OF CONTENTS

	PAGE
LIST OF TABLES	
LIST OF FIGURES	
ABSTRACT	
CHAPTER 1	1
INTRODUCTION	
CHAPTER 2	4
LITERATURE REVIEW	
2.1	4
Introduction	
2.2	7
Design requirements of direct drills	
2.3	10
Tillage, fertilisation and crop yields	
2.4	12
Effect of tillage on germination and seedling emergence	
2.5	13
Nutrient and moisture distribution in direct drilled and cultivated soils	
2.6	14
Nutrient movement in soil and availability to the plant roots	
2.7	15
Effect of fertiliser on germination and seedling emergence in conventionally cultivated soils	
2.8	16
Fertiliser placement in conventionally cultivated soils	
2.9	19
Fertiliser placement in direct drilling	
CHAPTER 3	21
EXPERIMENTAL METHODS AND MATERIALS	
3.1	21
Introduction	
3.2 A.	22
Small pot experiment	
3.2.1	22
Experimental design and layout	
3.2.2	22
Collection of undisturbed small soil blocks	
3.2.3	24
Pre-drilling treatment of pots	
3.2.4	26
Drilling of plots	

	PAGE	
3.2.5	Placement of seed and fertiliser	26
3.2.6	Counts of seedling emergence, irrigation and harvest	27
3.3 B.	Field experiment	29
3.3.1	Experimental design and layout	29
3.3.2	Herbicide spray and cultivation treatment	29
3.3.3	Drill coulter and fertiliser placement	32
3.3.4	Seed and fertiliser rates	36
3.3.5	Measurement of soil moisture	36
3.3.6	Plant counts and harvesting	36
3.3.7	Chemical analysis of leaf and stem for major elements	37
3.4 C.	Large bin experiment	38
3.4.1	Experimental design and layout	38
3.4.2	Selection of site	40
3.4.3	Collection of turf blocks	40
3.4.4	Preparation of turf blocks	40
3.4.5	Soil moisture measurement	43
3.4.6	Herbicide and pesticide application	46
3.4.7	Seed and fertiliser metering	46
3.4.8	Direct drilling of turf blocks	48
3.4.8.1	Horizontal placement of fertiliser	50
3.4.8.2	Seed and fertiliser, mixed placement	50
3.4.8.3	Vertical placement of fertiliser	50
3.4.9	Seedling emergence counts and germin- ation	53
3.5	Statistical analyses of results	56
3.6	Definitions	56

CHAPTER 4	RESULTS AND DISCUSSIONS	PAGE
		58
4.1	A. Small pot experiment	58
4.1.1	Seedling emergence	58
4.1.2	Initiation of seedling emergence and maximum seedling emergence delay	64
4.1.3	Yield	68
4.1.4	Summary	72
4.2	B. Field experiment	73
4.2.1	Overall trends	73
4.2.1.1	Plant counts	73
4.2.1.2	Delay in maximum plant counts	75
4.2.2	Mean trends	76
4.2.2.1	Fresh and dry weight yield	76
4.2.2.2	Major elements	77
4.2.2.3	Dry matter yield and drillings	79
4.2.2.4	Major elements and drillings	80
4.2.3	Individual results of each of the drillings 1-7, including time of drilling effects	82
4.2.3.1	Soil moisture	82
4.2.3.2	Plant count	84
4.2.3.3	Delay in maximum plant counts	89
4.2.4	Summary	92
4.3	C. Large bin experiment	93
4.3.1	Fertiliser placement effects	93
4.3.2	Soil moisture effects	95
4.3.3	Fertiliser treatment effects	96
4.3.4	Soil moisture and fertiliser placement interactions	98
4.3.5	Soil moisture and fertiliser interactions	102

	PAGE
4.3.6 Placement and fertiliser interactions	104
4.3.7 Summary	106
CHAPTER 5 DISCUSSION AND CONCLUSIONS	108
CHAPTER 6 BIBLIOGRAPHY	113
ACKNOWLEDGEMENTS	127
APPENDICES	128

LIST OF TABLES

		PAGE
1.	Effect of fertiliser placement on rape seedling emergence	58
2.	The effect of fertiliser placement at drilling on rape seedling emergence	63
3.	Effect of fertiliser placement on initiation and delay to reach maximum seedling emergence of rape	64
4.	The effects of fertiliser placement on yield of rape, 5 weeks after sowing	68
5.	Effects of cultivation treatment on plant counts of rape	73
6.	Effect of cultivation treatments on delay in maximum plant counts	76
7.	Effect of cultivation treatment on the fresh and dry matter yield of rape (numbers 1 and 2 drillings).	76
8.	The effects of cultivation treatment on the major elements of rape (leaf and stem) at flowering stage (1 and 2 drillings)	78
9.	Effect of time of drilling and cultivation treatment on the dry matter yield of rape at flowering	79
10.	The effect of time of drilling and cultivation treatment on the major elements of rape (leaf and stem) at flowering stage (drilling numbers 1 and 2).	81
11.	Effect of time of drilling on the soil moisture content due to cultivation treatment	83
12.	Effect of time of drilling and cultivation treatment on plant counts of rape on day 20 from sowing	84
13.	The effects of drilling time and cultivation treatment on delay in maximum plant counts of rape	90
14.	The effects of fertiliser placement on seedling emergence, status of seed in the groove and delay in maximum seedling emergence	93
15.	Effects of soil moisture (dry, wet) on seedling emergence, in-groove seed status and delay in maximum seedling emergence of rape	96
16.	The effects of fertiliser treatments on direct drilled rape	97

	PAGE
17. The effects of soil moisture and fertiliser placement treatments on rape seedling emergence, seed status and delay in maximum seedling emergence	99
18. The effects of soil moisture and fertiliser treatments on the seedling emergence, in-groove seed status and delay up to maximum seedling emergence	103
19. Effect of fertiliser and placement treatments on the seedling emergence, in-groove seed status and delay in maximum seedling emergence of rape	104
20. The effect of placement and fertiliser treatments on dead seeds of rape on day 20 after sowing	105

LIST OF FIGURES

		PAGE
1.	Plot layout of small pot experiment	23
2.	Tools designed and used in the small pot experiment	25
3.	A typical view of the pattern of holes drilled for horizontal placements and vertical or mixed placement	25
4.	The filling of "pre-drilled" holes and earthworm activity	28
5.	"Pre-drilling" and clearing of the holes	28
6.	Plot layout of field experiment	30
7.	Improved chisel coulter (side view)	33
8.	Cross-section of a groove formed with the improved chisel coulter showing seed and fertiliser placement	33
9.	Rear view of the press wheels and test rig, in a rotary hoed plot	34
10.	Test rig and tractor, direct drilling	34
11.	Chisel coulter and cross section of the groove showing seed and fertiliser distribution	35
12.	Seed and fertiliser placement after direct drilling	35
13.	Experimental design and layout of the large bin experiment	39
14.	Bin collection technique; bin is connected to turf cutter	41
15.	Bin collection technique; initial penetration of bin into soil	41
16.	Bin collection technique; tillage bin at full depth	42
17.	Bin collection technique; tillage bin being removed with a front end loader	42
18.	Turf block samples in the glasshouse during drying	44
19.	A specially constructed lowbed wheeled trolley straddling a turf block	44
20.	Open end of a turf block, after coating with paraffin wax	45

	PAGE
21. Seed metering unit of the vacuum operated seeder on tillage bin	45
22. An external forced feed fertiliser metering unit	47
23. Direct drilling in progress on the tillage bin	47
24. The turf blocks resting on the support beds after direct drilling	49
25. A top view of the groove formed by the improved chisel coulter	49
26. The groove configuration of horizontal placement	51
27. The groove shape after mixed placement of seed and fertiliser	51
28. A side view of the modified improved chisel coulter	52
29. The depth control wheel attached on the modified improved chisel coulter	52
30. A cross-sectional rear view of the modified improved chisel coulter	54
31. A side view of the vertical placement coulter assembly in the soil	54
32. The groove appearance and plant establishment after vertical placement of fertiliser	55
33. The divots formed by the scoop samples in the turf blocks	55
34. The effects of fertiliser placement on seedling emergence of rape	59
35. Typical seedling emergence patterns on day 7	61
36. Typical seedling emergence on day 13	61
37. The effect of no fertiliser and fertiliser placement on seedling emergence	63
38. Effect of horizontal and vertical placement of fertiliser on initiation and delay of maximum seedling emergence of rape	66
39. The effects of fertiliser placement on dry matter yield of rape	69
40. Typical growth patterns of seedling emergence and growth	71
41. The effect of cultivation treatment on plant counts of rape	74

		PAGE
42.	The effects of cultivation treatment on rape plant counts; Drilling 1	85
43.	The effects of cultivation treatment on rape plant counts; Drilling 2	85
44.	The effects of cultivation treatment on rape plant counts; Drilling 3	86
45.	The effects of cultivation treatment on rape plant counts; Drilling 4	86
46.	The effects of cultivation treatment on rape plant counts; Drilling 5	87
47.	The effects of cultivation treatment on rape plant counts; Drilling 6	87
48.	The effects of cultivation treatment on rape plant counts; Drilling 7	88
49.	Correlation between drilling time and delay in maximum plant counts	91

ABSTRACT

This study was conducted to evaluate the effects of dry fertiliser placement as a function of design criteria for direct drills.

The study was conducted in three parts.

1. Rectangular turf blocks (140 x 140 x 200 mm) of undisturbed soil were taken from a Tokomaru concretionery silt loam soil, site of permanent pasture. Seed and fertiliser placement was achieved by removing 2.5 mm diameter soil cores at 20% (d.b.) soil moisture content. Ammonium sulphate (21-0-0) was applied at the rate of 60 kg N ha⁻¹. It was either mixed with rape seed (*Brassica napus* L. c. Tower) or separated from the seed by 10 or 20 mm of soil, horizontally or vertically. A control treatment had no fertiliser. Where seed and fertiliser were mixed or separated vertically by a 10 mm soil core, seedling emergence was reduced significantly ($P < 0.01$) compared to control. Where separated horizontally by either 10 or 20 mm of soil, or vertically by 20 mm of soil, emergence counts were similar to no fertiliser placement. Initiation of emergence was significantly ($P < 0.05$) more rapid with 20 mm separation than with only 10 mm or no separation (mixed) of seed and fertiliser. Maximum seedling emergence counts were significantly ($P < 0.05$) delayed when seed and fertiliser were either mixed or horizontally separated by 10 mm or vertically separated by 10 or 20 mm. Horizontal separation of fertilizer by 20 mm from seed produced significantly more height, weight and total yield than the mixed or 10 mm placements, harvested 5 weeks after sowing ($P < 0.05$).

2. An improved chisel coultter was used for drilling rape seed with simultaneous fertiliser placement in cultivated and uncultivated Tokomaru silt loam soil under field conditions. Ammonium sulphate (75kg-N ha^{-1}) was placed along with the seed, horizontally separated by 20mm of soil. Significantly greater plant populations ($P < 0.01$) were obtained with direct drilled plots compared to plots cultivated a week before drilling. This trend was more pronounced at lower soil moistures (19-20% db) at the time of drilling than higher ones (23-37%).

3. Direct drilling of large turf blocks (1.8 m x 660 mm x 200 mm) was carried out in the laboratory using both the improved chisel coultter and the modified version. The blocks were extracted from the same pasture as in 1 above. Horizontal and vertical placements of ammonium sulphate and mono-ammonium phosphate fertilisers at 20mm from the rape seed and at rates of either 30 or 60 kg-N ha^{-1} largely resulted in higher germination and fewer dead seeds compared to mixed seed and fertiliser placements. Placements of fertiliser in wet soil and horizontal placements in dry soil tended to produce higher germination percentages and fewer viable seeds. The interaction of fertiliser x placement indicated that mono-ammonium phosphate (16-9-0) mixed with rape seed was likely to cause more dead seeds than at 20mm placement.

It appears from the results of these 3 experiments that the horizontal separation of fertiliser by 20mm from rape seed was desirable from the point of view of germination, seedling emergence, initiation of emergence, delay in maximum seedling emergence and yield characteristics of plants. With this fertiliser placement arrangement plant populations in uncultivated soil were greater (up to 30%) than in cultivated soil. The improved direct drilling

chisel coulter was capable of achieving this fertiliser placement objective without modification.

1 INTRODUCTION

Interest in direct drilling in many parts of the world is growing as farmers and researchers experiment with this newly discovered, but anciently principled concept. The technique offers a number of advantages over conventional tillage practices, especially in the areas of conservation of energy, time, water and soil (Phillips *et al* 1980).

Inorganic fertilisers are an essential input in modern agriculture. In conventional cultivation techniques, the fertilisers can be applied through various implements and at different times of seedbed preparation, sowing or crop establishment. The easily manipulated soil after tillage offers easy machinery penetration and thereby increases flexibility of fertiliser placement. In direct drilling fertiliser application at present is limited to surface broadcasting or mixing of fertiliser with the seed in the soil (if not in the seed hopper) during sowing.

Some surface applied fertilisers are at risk from volatilization or fixation losses and often depend on rain or irrigation water for their downward movement. There may also be preferential movement of water soluble nutrients down cracks and worm channels, thus distributing the nutrients unevenly (Scotter 1978; Kanchanasut *et al* 1978). Mixed fertiliser and seed may risk adverse effects on germination and seedling emergence (Carter 1969; Baker 1979; Olson and Dreier 1956; and Cooke 1960).

Direct drilling, on the other hand, has often resulted in accumulation of nutrients near the soil surface (Triplett and Van Doren 1969; Drew and Saker 1975; and Ketcheson 1980). The technique has given either poorer (Ketcheson 1980; Riley *et al* 1975), similar (Baeumer 1970) or increased (Triplett and Van Doren *loc cit*) yields compared to conventionally cultivated crops in response to applied fertilisers. Uncultivated soils have also been reported to be more resistant to structural damage (Hughes and Baker 1977), and have resulted in increased soil moisture, earthworm population and improved soil temperature regimes (Triplett and Van Doren 1969; Soane *et al* 1974)

Despite evidence of the positive effects of direct drilling on soil physical properties, which might or might not indirectly affect soil fertility, there have been few reported experiments to examine the relationships between different methods of applying fertiliser and seed, and plant responses in direct drilling.

At the same time the recent development of a chisel coulter with the claimed capability of placing seed and fertiliser simultaneously, (but separated by 20mm) in the soil, offered promise of greater flexibility in fertiliser application during direct drilling (Baker *et al* 1979). It was by no means clear though whether or not horizontal placement of seed and fertiliser was superior to vertical placement by the same distance, or indeed mixing of the two together. The experiments reported here were therefore conducted to explore some basic aspects of dry fertiliser placement, mainly in uncultivated soil, under semi-controlled and field conditions. The primary objective of the study was to

ascertain the design criteria for simultaneous seed and fertiliser placement equipment in the direct drilling of cereals and brassicas.