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DIRECT DRILLING (NO-TILL) OPENER DESIGN SPECIFICATIONS AND SOIL MICRO-ENVIRONMENTAL FACTORS TO INFLUENCE BARLEY SEEDLING ESTABLISHMENT IN A WET SOIL

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The aim of this study was to determine the interactions between direct drilling opener design specifications and seed groove micro-environments responsible for seed/seedling performance in a wet soil. Three openers the winged, hoe and triple disc were used. In the presence of earthworms and crop residue, the winged opener which created inverted T-shaped groove, together with hoe opener (U-shaped groove) resulted in greater number of seedling emergence, oxygen diffusion rates and earthworm activity than V-shaped groove created by the triple disc opener. In the absence of earthworms the openers and crop residue had no positive effect on micro-environments around the grooves. A compacted zone adversely affected the seedling performance and earthworm activity around the groove profiles.

INTRODUCTION

Several authors (Baker, 1976; Choudhry and Baker, 1980) have defined the requirements of seeds and seedlings drilled direct into dry, untilled soils. Direct drilling machinery technology has now been developed in New Zealand and Australia which is able to meet these requirements. Internationally direct drilling is primarily used in dry soils, and early research work on direct drilling was also undertaken on dry soils.

Not much research work has been undertaken in wet soils. Ellis *et al.* (1975) and Lynch *et al.* (1980) highlighted the problem of fatty acid production from decaying plant residues and the resulting seedling mortality in the cold saturated soils of the United Kingdom. They reported that applications of substances which neutralised acetic acid and separation of the seed and plant residue, overcame the problem, but they did not identify differences amongst opener designs in terms of their ability to separate the seed from the plant residues.

This paper summarises the results of a series of experiments in which the micro-environmental requirements of barley seed (*Hordeum vulgarae*) drilled direct into a Tokomaru silt loam soil which subsequently became very wet. Attempts to define design criteria for the openers of seed drills were made and the management practices to overcome the problems associated with wet soils and crop residues are discussed.

MATERIALS AND METHODS

Details of materials and methods and individual experimental results have been reported by Chaudhry (1985), Chaudhry *et al.* (1987), and Baker *et al.* (1988). Four experiments were carried out. Each was a split plot design with three replicates.

Experiment 1 compared seed and seedling responses from slots made by three openers in plots with different amount of residues. These plots were split for irrigation and no-irrigation. Experiment 2 examined the same openers and residue treatments as in Experiment 1, but was conducted under irrigation and in the partly controlled atmosphere of a glasshouse. Measurements included seed and seedling responses, earthworm numbers and oxygen diffusion rates.

Experiment 3 compared the same opener and residue treatments as in experiments 1-2 in the glasshouse. It also compared effects arising from earthworms with those where natural earthworm numbers were maintained. Experiment 4 was conducted to prove the effects of direct opener design specifications on the response of earthworm activity around the seed grooves made by these openers.

The experiments were conducted both in the field and laboratory. In the field experiments broad responses to excessive irrigation and the presence of surface residue were determined, while in the laboratory experiments undisturbed soil from the field was collected in large bins (up to 0.5 tonne each) and irrigated in a glasshouse so that the climate around the seed would be controlled after drilling, and the fate of seedlings monitored. The temperature, moisture content and bulk density of the soil in the groove produced by each opener was also monitored. The seeds in the field and laboratory experiments were drilled at a normal speed (8 km/hr) and at a normal soil moisture level, since few openers would normally drill seed into an already saturated soil. The soils in the field were then saturated using spray-irrigation. In the laboratory, garden soak hose was used to wet the soils in their bins at the rate of 5 mm/hr. In this way, soils were soaked for 4 hours per day for a period of 21 days. Ambient temperatures in the glasshouse were maintained at 20-25^{o}C (night and day) in some experiments (2 and 3) and at 15-20^{o}C in experiment 4.

The drill openers and their resulting soil slots are described as follows:

Winged opener: This created a closed groove with an invert T-shape by returning the residue-covered soil over the groove. The seed and residue were physically separated by distance of 40 mm.

Hoe opener: This created an uncovered groove with U-shape by sweeping residue to either side of the groove. The seed and residue were separated by a distance of about 50 mm.

Triple disc opener: This created an uncovered compacted groove with a V-shape. A proportion of the residue was pushed into contact with seed.

The number of seedlings which emerged was counted. Visible seedlings from all treatments were therefore listed as "Seedling emergence". Counts were also made of ungerminated seeds which had germinated but not emerged from the soil. Cylindrical cores of 120 mm diameter and 100 mm depth centered on the rows were taken around the slot made by the openers, and the number of whole earthworms present was counted. The oxygen diffusion rate (ODR) was measured *in situ* in a 16 point grid pattern to one side of and below the seed (Letey and Stolzy, 1964). Soil bulk density and moisture contents were measured in soil sampled in a similar grid pattern on the other side of the seed.

To study the effect of soil compaction on earthworm activities a bare soil surface in the experimental field of Tokomaru silt-loam soil was compacted to three different soil bulk density levels (1.0 g/cm^3, 1.2 g/cm^3 and 1.4 g/cm^3) by using a heavy steel roller. The bare soil surface was created by removing all residual plant material 8 weeks earlier and the soil moisture content was 29% (d.b). From each compacted zone of undisturbed soil the samples (160 mm wide x 160 mm long x 200 mm deep) were cut with a spade and placed in plastic pot of the same size. All the pots were shifted to a glasshouse and were arranged in a completely randomized block design with three replicates. Three levels of smear (zero, light and heavy) were created on the surface of the soil using the back of a spatula. No drilled grooves were made. "Light" smearing of the surface resulted from rubbing the spatula over the soil surface twice and "heavy" smearing by rubbing five times. No quantitative measurements of intensity of smearing were attempted.

To ensure a reasonable level of earthworm activity, crop residue was placed over the surface of all the pots after they had been smeared. Simulated rain conditions of 5 mm per hour for 4 hours per day were created by using a soak hose as described earlier. Daily measurements of cumulative numbers of earthworm holes in the soil surface of the pots were taken for 21 days. Statistical analysis of cumulative numbers of holes were made on days 1, 7, 15 and 21.

RESULTS

Seedling emergence and the earthworm populations of experiments 1,2 and 3 are summarised in Tables 1,2, and 3. In Tables 1 and 2 there was strong interaction in the number of seedlings emerging as a result of surface residue and openers, but only in the presence of earthworm (Table 1). Where earthworms were absent (Table 2) the only influence that either sowing method or residue had arisen from exaggerated mechanical aeration or from removing the seed from the soil and exposing it to the atmospheric oxygen and adequate water.

Where earthworms were present (Table 1), winged and hoe openers responded consistently and markedly to the presence of surface residue which was reflected in increased seedling emergence. This appeared to be directly influenced by both the number of earthworms and their activity around the groove (Table 3), both of which favourably influenced oxygen diffusion rate (Fig. 1-3) and the bulk density of the soil in the seed zone. The triple disc opener did not result in increased seedling emergence in the presence of earthworms and crop residue, probably because the decaying grass was pushed down into the groove with its compacted sides and base. The bulk density of the soil was lower around the grooves produced by each opener when the residue was present than when the soil was bare and all openers produced lower bulk densities than the triple disc opener. It is likely that the influence of soil compaction reflected earthworm activity since earthworms were generally high when bulk densities of the soil were lower.

Table 1. **Effects of direct drilling openers and surface residues on emergence of barley seedlings from a saturated soil with natural levels of earthworms (% seedling emergence)**

Experiments	Residue	Opener type				
Earthworms present		Winged	Triple disc	Hoe	S.E. differences opener	interactions
Field experiment (Irrigation)	No-residue	47.0	38.3	41.7	4.3	3.3
	Residue	75.0	30.0	67.7		
Tillage bin	No-residue	43.8	26.2	32.9		
(glasshouse-simulated rain)	Residue	73.3	25.2	63.8	3.2	1.1

Table 2. **Effects of direct openers and surface residue on emergence of barley seedlings from a saturated soil (% seedling emergence)**

Experiments	Residue	Opener Type				
Earthworms absent		Winged	Triple disc	Hoe	S.E. differences opener	interactions
Pot experiment	No-residue	63.3	53.3	60.0		
(glasshouse-simulated rain)	Residue	50.0	40.0	56.7	15.2	9.4

Table 4 indicates the effects of soil compaction and smearing on earthworm activity. It appears from Table 4 that there were strong interactions between smearing intensities and soil bulk densities. The combination of "zero" smear and soil bulk density of 1.0 g/cm^3 had clearly the highest cumulative numbers of earthworm holes (terminal, 120.7). Conversely, the combination of "heavy smear" and a soil bulk density of 1.2 or 1.4 g/cm^3 showed the lowest cumulative numbers of earthworm holes (terminal, 29.0 and 21.3 respectively), although at the higher levels of soil bulk density (1.4 g/cm^3), the three levels of smearing had little additional effect on reducing the earthworm activity. In fact, throughout the experiment, bulk density appeared to have a greater effect on numbers of earthworm holes than the intensity of smearing.

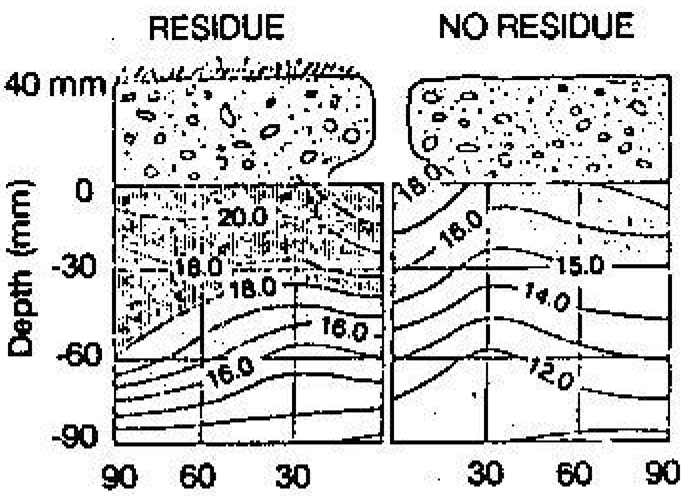
Table 3. Effects of direct drilling openers and surface residue on earthworm numbers in saturated untilled soil
(Number per soil core)

Experiments	Residue	Opener Type				
		Winged	Triple disc	Hoe	S.E. differences opener	interactions
Earthworm numbers						
1. Tillage bin (glasshouse-simulated rain)	No-residue	13.3	6.7	11.3		
	Residue	27.3	8.0	26.7	2.5	1.0
2. Pot experiment (glasshouse-simulated rain)	No-residue	19.3	16.7	14.7		
	Residue	25.3	25.7	28.3	6.1	5.3

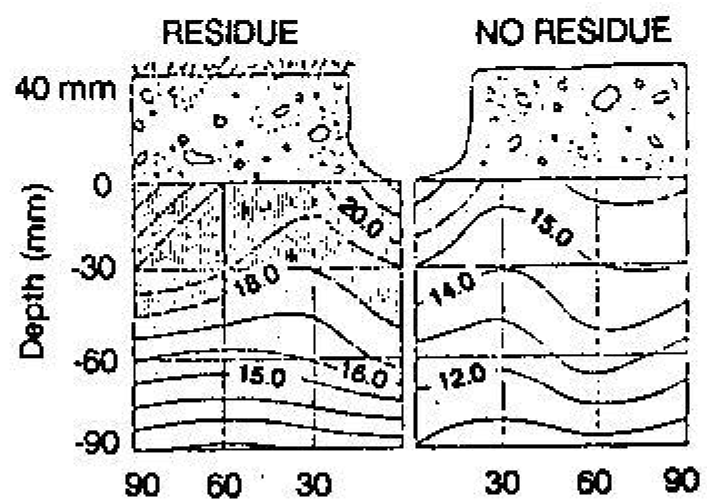
Table 4. Effects of smearing intensity and soil bulk density on cumulative numbers of earthworm holes, under simulated rain conditions

Days	Smear			Bulk density (g/cm^3)			Interactions				
	Zero	Light	Heavy	1.0	1.2	1.4	Bulk density/ smear	1.0	1.2	1.4	
	Holes per pot*										
1	5.4	4.2	3.6	8.8	3.0	1.4	Zero	12.3	3.3	0.7	
	Aa	Aab	Ab	Aa	Bb	Cc	Light	7.7	3.0	2.0	SED = 1.216
							Heavy	6.2	2.7	1.7	
7	35.2	26.4	16.8	49.6	26.4	16.8	Zero	59.3	29.3	17.0	
	Aa	Bb	Bc	Aa	Bb	Bc	Light	54.0	30.7	17.7	SED = 6.43
							Heavy	35.3	19.3	15.7	
15	57.1	48.2	34.1	79.9	38.0	21.6	Zero	103.3	45.3	22.7	
	Aa	ABb	Bc	Aa	Bb	Cc	Light	83.3	40.0	21.3	SED = 8.46
							Heavy	53.0	28.7	20.7	
21	64.7	51.1	37.7	91.8	39.6	22.1	Zero	120.7	49.7	23.7	
	Aa	ABb	Bc	Aa	Bb	Cc	Light	92.0	40.0	21.3	SED = 8.55
							Heavy	62.7	29.0	21.3	

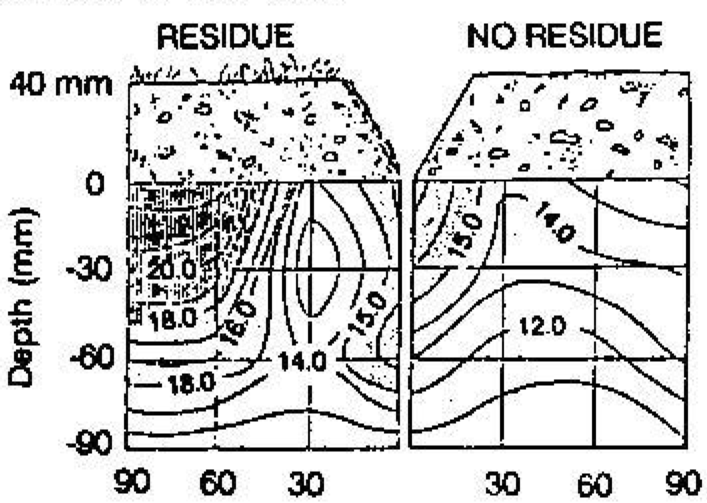
* Pot surface area = 0.0256 m^2.
Unlike letters in a row denote significant differences.
(Upper case: $P<0.01$; lower case: $P<0.05$).
SED = Standard error of all interactive differences.



Distance from groove centre (mm)
Fig. 1. Mean oxygen diffusion rates around winged opener grooves (days 5-20) (g x 10⁻⁸/cm²/min)



Distance from groove centre (mm)
Fig. 2. Mean oxygen diffusion rates around hoe opener grooves (days 5-20) (g x 10⁻⁸/cm²/min)



Distance from groove centre (mm)
Fig. 3. Mean oxygen diffusion rates around triple disc opener groove (days 5-20) (g x 10⁻⁸)/cm²/min)

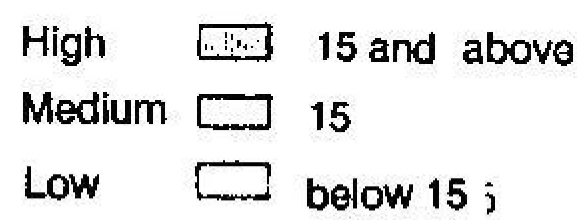


Fig. 1-3: Mean oxygen diffusion values around the groove profiles of winged, hoe and triple disc openers

DISCUSSION

The most vivid effect in these experiments was the contrast between the presence and absence of earthworms. In the absence of earthworms and perhaps other soil fauna there appeared to be a little effect of the openers or interaction with plant residue. In the presence of earthworms the winged and hoe openers increased emergence almost three fold and these openers benefitted markedly from crop residue. The effectiveness of the winged opener under these sub-optimal soil conditions is particularly noteworthy as it had earlier been shown to be similarly effective in very dry soil for different reasons (Baker, 1976; Choudhry and Baker, 1980). This indicates a wide tolerance of varying soil conditions by this opener. With the triple disc there were interactions between openers and plant residue, but these reduced seedling emergence. It is probable that the triple disc opener may have increased contact between seed and the residue. This opener was also observed by Mai (1978) to reduce porosity close to the groove which is an observation that was confirmed by the iso-ODR figures in these experiments (Fig. 1-3).

The failure of the triple disc opener might be explained by the lower porosity (Mai, 1978) and decaying residue which appeared not only to have a direct mortality effect on seeds, but also to have discouraged earthworm activity. Earthworm numbers were closely related to both bulk density and oxygen diffusion rates which were themselves related, and both appeared to have an influence on seedling emergence. Because the earthworms were sensitive to soil compaction and oxygen and their behaviour was similar whether they were getting out of the soil or entering into the soil.

Conclusions:

1. The influences of openers and residues on seed and seedling performance in a wet directly drilled soil appears to centre around their influence on earthworm activity, bulk density and oxygen diffusion rate in a zone close to the drilled grooves.

2. When direct drilling takes place in soils with reasonable populations of earthworms, satisfactory levels of seedling emergence might be expected to occur if winged opener is used. Hoe opener will also perform satisfactorily provided plant residue is present.

3. In wet soils, regardless of the presence or absence of earthworms or residue, triple disc opener is likely to result in poor seedling emergence and low ODR regimes around the groove profiles. The compacted soil adversely affects seed/soil micro-environments and particularly the activity of soil fauna.

By giving attention to the shape of the seed groove created by drill openers, and deliberate positioning of surface residues, it seems possible to promote direct drilling (no-tillage) with a substantially lower biological risk in a range of field conditions, than is being achieved by some of the narrow-tolerance technology currently in use.

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