Direct drilling with a modified combine improves root growth, and wheat yields in compaction-prone, wind-erodible soils

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Summary. The effects of tillage methods and times of sowing on root growth and yield of wheat, *Triticum aestivum* were examined in the northern wheatbelt of WA. Conventional establishment methods were compared with direct drilling, deep-tillage sowing and a new cultivationdepth-modified (CDM) direct drill. Crops sown with the CDM or after deep tillage had lower soil strength and higher root length densities in the upper 20 cm section of the soil profile, and produced more grain than crops sown with conventional direct drilling or after cultivation. Early sown CDM and direct drilled crops consistently out-yielded crops sown later with conventional methods. Deep ripped crops out-yielded all other treatments sown at the same time. However, economically, this method was not always the most viable option.

Introduction

Farmers practising direct drilling on West Australian sands and loamy sands have consistently reported early shoot growth of wheat (6). This growth difference can persist until harvest, when crops sown after cultivation may yield up to 20% more grain than crops sown by direct drilling (4). Early root growth of wheat is also restricted by high soil strength, particularly after direct drilling (3). However, direct drilling reduces the length of exposure of these fragile soils to erosive wind. The use of conventional tillage practices requires several tractor passes, often over moist soil susceptible to sub-soil compaction. Increases in the number of tractor passes on loamy sands have resulted in an increase in sub soil strength, and a decline in wheat yields *as* the number of passes increased, with three runs being sufficient to cause significant reductions in yields of 15% (5,8). This sub-surface compaction can markedly restrict deeper root growth. One response to this problem is the use of deep tillage. Field trials and farmer experience in the northern wheatbelt have shown that deep ripping can increase wheat yields by up to 40% of the average yield obtained without deep tillage (7,9). However, this method of crop establishment requires several tractor passes, a yield increase of at least 300 kg/ha to be profitable, can delay seeding and exposes the soil to wind erosion (1).

The date of sowing has an economically significant influence on wheat yield, with a yield penalty of 100 kg/ha per week for each week that seeding is delayed after 20 May, the expected date of the first winter rains (2). A successful direct drilling method should maximise profitability by improving crop yields, increasing root growth, allowing earlier sowing, reducing soil compaction and reducing the risk of wind erosion. Therefore a new direct drilling method, the Cultivation Depth Modified Combine, or CDM, has been developed (6). The CDM is a modified direct drill that allows the cultivation depth of the front tynes to be altered so that there is greater soil disturbance beneath the seed. This seeding method is effectively a one-pass direct drilling system which creates the same soil disturbance *as* a conventional cultivate/sow technique. This study aimed firstly to determine the effects of different cultivation and sowing methods on root growth, soil strength and wheat yields and secondly to examine the interaction between tillage methods and time of seeding.

Methods

Sites were chosen to represent the variation in soil types and grass weed burden normally expected on the northern sandplain in WA. The experimental program was divided into two areas:

(a) A trial examining the effect of the depth of disturbance on soil strength, shoot and root growth, and the resulting yield. This trial was carried out on an Earthy sand (Northcote:Vc 5.22), was a randomised complete block design with four replicates, and five tillage methods. These were:

- normal direct drill (DD);

- CDM6 (cultivating to 6 cm, i.e., 2 cm below the seed);
- CDM10 (cultivating to 10 cm, so as to give the same depth of soil disturbance as normal cultivate/sow);
- cultivate/sow (CS);
- deep rip (DR) to 30 cm after sowing.

All treatments (except the deep ripping operation) were carried out with the CDM machine with the 15 cm wide front cultivating tynes level with or deeper than the rear seeding tynes. Rear tyne width was 10 cm for the DD, CS and DR treatments, and 5 cm for the CDM treatments. The CDM treatments had the rear tynes moved in-line with the cultivation tynes. Measurements of wheat root length and distribution per 10 cm soil depth were made by excavating an area four rows wide by 20 cm deep to a depth of 100 cm two, three, four and five weeks after sowing. This method was also used for the DD, CDMIO and CS treatments six weeks after sowing. Two 10 cm soil cores per plot, one in and one between the crop rows were taken to a depth of 1 m for the CDM6 and DR treatments of week 6 and for all treatments at week 10. Root lengths were measured by the root intersection method (10). Each month measurements were made to 45 cm depth of soil strength (using Rimik Penetrometer), and the readings for the first 21 cm summed to give an index of soil strength over this depth.

(b) Experiments concerned with the interaction between tillage method and time of sowing. Trials were conducted on four sites in 1989, and three in 1990. The trials were established using the CDM combine, and consisted of four different tillage treatments and two times of sowing, the second time of sowing being 10 days after the first. In the second year an additional zero tillage treatment was added (using narrow sowing tynes only). The experiment was a randomised split plot design, split for two varieties, with three replicates. Tillage methods examined were:

- direct drill (DD5), using 5 cm sowing tynes only; normal direct drill (DD);
- CDMIO (i.e., cultivating to 10 cm);
- cultivate/sow (CS), 10 days later;
- deep rip (DR) to 30 cm after sowing.

Results and discussion

Effect of depth of soil disturbance on root growth and wheat yield

Wheat yields are presented in Table 1. At week 5 although there were no significant differences between treatments in either the 10 or 20 cm section of the profile, at the 20 cm depth the CDM 10 treatment had about 35% greater root length than the DD or CS treatments. Also at this depth, the DR treatment had about 38% more root length than the DD or CS treatments. The DD and CDM6 treatments had similar root lengths, slightly greater than that of the CS treatment, for each soil depth. Root length at 20 cm for the week 5 sampling was also correlated with wheat yields ($r=0.52$, $P<0.05$).

The DR treatment showed a significant decrease in soil strength and a significant increase in wheat yield relative to all other treatments (Table 1). For all treatments, however, yield was found to be significantly correlated with soil strength, defined by the penetrometer index (Table 1; $r=0-.576$, $P<0.01$). Although the CS and CDMIO treatments were cultivated to a similar depth, the soil strength of the CS treatment is similar to that of the 'one-pass' DD and CDM6 treatments, possibly indicating recompaction of the soil during the sowing operation. The lower soil strength of the DR treatment resulted in unrestricted root growth in the 10 cm section of the profile, and continued root growth through the 20 cm depth to 1 m.

These correlations indicate that the lower soil strengths and higher yields after establishment with the CDM technique may enable farmers to continue direct drilling, while reducing the yield penalties usually associated with DD. This system does not incur the costs and possible delay of seeding associated with deep ripping, and reduces the risk of soil erosion.

Table 1. Effect of tillage treatment on soil strength and wheat grain yields.

Treatment	Yield (kg/ha)	Accumulated Soil Strength to 21 cm (kPa)
DD	1796	8961
CDM6	1742	9255
CDM10	1871	7509
CS	1729	8994
DR	2158	1824
l.s.d. (P=0.05)	229	2457

Interaction between tillage method and time of seeding

The results of the effect of tillage method and time of sowing on wheat yields for 1989 and 1990 are presented in Table 2. Although poor seasonal conditions resulted in depressed wheat yields in 1989, significant ($P<0.05$) yield penalties were observed for delayed sowing, under DD, CDM and CS tillage treatments, in both years. At five of the seven sites, early sown CDM and DD treatments significantly ($P<0.01$) out-yielded the traditional cultivate/sow technique, thus illustrating the yield advantages possible using early seeding/direct drilling techniques.

Given that the DR treatment must yield 300 kg more than the DD treatment to be profitable, these results show that the early CDM method is generally more profitable than deep ripping, and reduces the risk of soil compaction and wind erosion.

Although at some sites in both years the early sown CDM treatment showed a significant ($P<0.01$) yield advantage over the DD treatment, this difference was not consistent. This was possibly due to the difficulty of accurately controlling cultivation depth during the tillage operations, resulting in similar cultivation depths for both DD and CDM treatments. Direct drilling with narrow tynes (DD5), in the second year, resulted in lower wheat yields than all other tillage treatments at two of the three sites for the early sowing, and at all later sowings. When compared with the DD treatment, an average yield penalty of 357 kg/ha was observed in the late sowing. However, the early DD5 treatment out-yielded the later CS treatment at all sites.

The results from this trial clearly illustrate that the time of sowing has a more important effect on wheat yield than does the tillage method used.

Table 2. Effect of tillage/sowing method and timeliness of sowing on yields of wheat (kg/ha); two varieties (1989) and one variety (1990).

Year	1989				1990		
Site	1	2	3	4	1	2	3
		Early Sown					
DD5	-	-	-	-	2622	1468	583
DD	864	1253	411	734	2600	1583	1618
CDM10	1125	1314	477	787	2660	1506	1882
DR	1471	1460	758	1112	3135	2077	1799
		Late Sown					
DD5	-	-	-	-	1731	692	993
DD	574	1075	272	978	2103	1051	1333
CDM10	510	1056	297	750	2135	968	1375
CS	565	1064	252	1050	2346	1263	1347
DR	1134	1412	517	1385	2865	1526	1722
SED	60.3	51.4	40.1	41.5	173.5	90.2	74.8

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