Effect of residue type on the performance of no-till seeder openers

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INTRODUCTION

No-till farming is an economically viable, erosion limiting crop production system in which the crop is planted directly into the previous crop’s stubble with minimum soil disturbance (MNZTFA 1998). As tillage operations are not required, no-till producers do not need to purchase tillage implements. This, together with the reduced labour and tractor hours, reduces the crop production cost. In recent years, no-till systems have been identified as a major practice to reduce greenhouse gas (carbon) emissions from agriculture (Lindstrom and Reicosky 1997).

As early as the mid-1960s, concerns about erosion, time spent in the field, and increasing energy costs persuaded a small number of farmers in the prairies of North America to try directly seeding crops into the standing stubble from the previous year (Coutts et al. 1991). Due to an inability to control pests and weeds and an unavailability of proper seeding equipment, producers did not embrace no-till farming. In the years since, advances in technology have improved pest and weed control, and more producers have switched their conventional tillage systems to no-till systems. However, no-till farming is still limited to a small fraction of producers. High levels of crop residues present a major constraint to the adoption of conservation tillage because residues mechanically interfere with seeding operations (Carter 1994). The success of any no-till crop production system is the ability to not only effectively control the crop pests and weeds, but also effectively deal with surface crop residue in the seeding operation and to establish adequate plant populations (Tomkins 1985).

Seeding performance of seed openers can be evaluated by the seeding depth, the uniformity of seeding depth, and the early crop performance, such as speed of crop emergence and plant populations. Both seed opener and residue type affect the seeding performance. Insufficient seeding depth results in a poor crop emergence (Janelle et al. 1993). Deep seed placement delays plant emergence (Loeppky et al. 1989). Constant seeding depth is important to achieve uniform crop emergence (Wells et al. 2001). Tracked furrows (seed furrows inside wheel track) were found to have a larger mean cone index than non-tracked furrows (furrows outside wheel track) (Isaac et al. 2002). Soil cone indices affect...
Table 1. Precipitation and degree days recorded at the field location.

<table>
<thead>
<tr>
<th>Seeding season</th>
<th>Rainfall (mm)</th>
<th>Degree days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>May</td>
<td>June</td>
</tr>
<tr>
<td>2001</td>
<td>70</td>
<td>168</td>
</tr>
<tr>
<td>2002</td>
<td>5</td>
<td>65</td>
</tr>
<tr>
<td>30 year average</td>
<td>52</td>
<td>72</td>
</tr>
</tbody>
</table>

the crop growth (Ehlers et al. 1983; Chen et al. 2004a). Little research has been done to examine if seed placement inside the wheel track is different from that outside the wheel track.

It has been well documented that crop rotation is a vital technique to implement no-till farming. Appropriate crop rotation tends to reduce the use of pesticides and herbicides. However, little research has been done to determine the best previous crop for favourable seed placement and crop emergence. The primary objective of this study was to investigate the seeding performance as affected by the type of no-till seed opener and the type of residue from the previous crop. The seeding performance was assessed by seed placement and crop emergence. The secondary objective was to examine seed placement as influenced by field wheel tracks.

**MATERIAL and METHODS**

**Site description**

A field study was carried out in 2001 and 2002 on plots from an on-going crop rotation trial at a location approximately 25 km north of Brandon, Manitoba. The field had Newdale clay loam (chernozem) (45% clay, 40% silt, 15% sand) with 5% organic matter. The site was no-till with canola, pea, and wheat as the previous crops, which were swathed at approximately 0.2 m in stubble height. In this study, the plots were seeded with canola using two typical no-till seeder openers. Fertiliser (urea and monoammonium phosphate) was applied at the recommended rate. Different plots were used in the second year of study to maintain the same residue treatments. The weather conditions at the site are summarised in Table 1.

**Seeding equipment**

**Disc seeder** The ST AgriTech disc seeder (ST AgriTech, Winnipeg, MB) (Fig. 1a) was 3.7 m wide, with 12 Ponik no-till disc openers (Janelle et al. 1995) at a 300 mm spacing, with fertiliser applied between alternate seed rows. This Ponik opener consists of two large offset discs. The smaller disc (380 mm diameter) is oriented vertically, whereas the larger disc (460 mm diameter) is angled relative to both the direction of travel and the vertical axis. This orientation helps the discs cut through residue and soil, as well as displace a volume of soil forming a seed furrow. The adjustable gauge wheel (410 mm diameter by 100 mm wide) for seeding depth control was located beside the small disc and a steel press wheel (360 mm diameter by 13 mm wide) was located behind the discs. A spring-loaded parallel linkage system applied the down force on the opener (Gratton et al. 2003).

**Hoe seeder** The ConservaPak hoe seeder (ConservaPak Seeding Systems, Indian Head, SK) (Fig. 1b) seeds and fertilises in one pass. The seeder used was 3.7 m wide and had four ranks with 16 openers spaced 225 mm apart. The fertiliser opener was mounted to a shank, and the seed delivery tube dropped fertiliser behind the shank. The seed opener was arranged behind the fertiliser opener. The vertical height of the shank and the seed opener could be adjusted to achieve different depths of seed placement relative to the fertiliser placement. A press wheel controlled the overall depth of the opener to achieve desired depths for seed placement and fertiliser placement. The fertiliser placement was 30 mm beside and 25 mm below the seed row. It was assumed that the fertiliser placement did not have any impact on the crop emergence.

**Experimental design**

A split-plot experiment was used with a completely randomised design (CRD). The main plots consisted of three different residues: canola, wheat, and pea, and the two sub-plots were seeded with disc and hoe openers. Canola and pea residue

![Image](a)

![Image](b)

Fig. 1. Openers used for seeding: (a) ST AgriTech seeder with double disc openers; (b) ConservaPak seeder with hoe openers.
treatments were replicated four times, while wheat residue treatment was replicated eight times due to the crop rotation. Seeding canola after canola is not a common practice but was included as one of the treatments in this study, since it is currently possible to control weeds while this was not possible prior to the introduction of a new herbicide. A total of 32 plots was included in the study (Fig. 2). The roadways between plots were 15 m wide, and there was no movement of the tractor or the seeder over the plot area except during the actual seeding operation.

Seeding operation

Seeding was performed on June 8, 2001 and May 14, 2002, under normal and dry seeding conditions, respectively. The seeders were operated at 5 km/h. Canola was planted at the recommended rate (6 kg/ha) using certified seed. The seeding rate was calibrated using the same seed. The calibration was done by using a hand crank and measuring the seed output for a given number of turns which corresponded to a specific travel distance. This was repeated three times and the average output was used to calculate the seeding rate. The seeding depth was calibrated on the cereal ground outside the plot area. This was done by measuring the distance from the soil surface to the seeds on the four openers of each seeder. Hoe openers were levelled from front to back ranks prior to the calibration. This was not required for disc openers since all discs were on one toolbar. The same seeding rate and depth were set for both seeders and all three residue treatments.

Field measurements

Residue cover A 1-m² quadrat was randomly placed on the surface of each plot. The surface straw contained within the quadrat was manually collected and placed into paper bags. Sampling was performed at three random locations per plot. The residue samples were oven-dried at 60°C for 72 h (ASAE 1999a) and then weighed to determine the dry mass of the residue per hectare (kg/ha).

Soil moisture content To determine the gravimetric soil moisture content, a 20 mm diameter probe was used to collect five random samples per plot. Sampling was performed at depths of 0-50 and 50-100 mm. Greater depths were not investigated, as they were not expected to affect the seed placement and crop emergence. Samples at each depth were pooled to form a composite sample. In the laboratory, the soil samples were weighed, oven-dried at 105°C for 24 h, and weighed again to determine the gravimetric soil moisture content.

Soil cone index Following the seeding operation, soil cone indices were randomly taken at each plot with six locations inside the wheel track and six outside the wheel track induced by the tractor in the seeding operation. The value of the soil cone index at each 20 mm depth interval was recorded to a depth of 100 mm. A Rimik electronic soil penetrometer (Model CP 20 Agridy Rimik Pty. Ltd., Tooowoomba, Australia) was used for these measurements. The soil penetrometer conformed to the standards set by ASAE (1999b).

Speed of crop emergence Plant counts were performed at three random locations in each plot with three rows at each location (a total of nine rows per plot). In each row, a length of 600 mm was staked out and the number of canola plants within this length was counted on the 4th, 7th, 10th, 17th, and 24th day after the first emergence. The speed of crop emergence per unit area was calculated using Eq. 1 (Tessier et al. 1991).

\[
S_E = \frac{\sum N_i d_i}{L s}
\]

where:
- \(S_E\) = speed of crop emergence (plants d\(^{-1}\) m\(^{-2}\)),
- \(N_i\) = number of newly emerged seedlings counted per day \(d_i\),
- \(L\) = length of row counted (m), and
- \(s\) = row spacing (m).

The final plant count (on the 24th day) was used to determine the plant population (plants/m\(^2\)).

Seeding depth The chlorophyll-free stem and the coleoptile’s length (from the seed remnants to onset of the green stem) is a good representation of the effective seeding depth (Tessier et al. 1991) of cereal crops. However, it is not possible to measure the seeding depth of canola using this method because canola seeds do not remain in the soil. For the purpose of seeding depth measurements of canola, a 1:1 portion of canary seed was mixed with the canola (Chen et al. 2004a). Among the common cereal crops, canary seed is the most similar seed to canola, in terms of physical properties and growth characteristics. The chlorophyll-free stem and coleoptile’s length of the canary seed seedling was measured as the effective seeding depth of the canola. For this measurement, six locations were randomly selected in each...
Table 2. Mean residue cover for different types of residues and mean gravimetric soil moisture content at different depths at time of seeding for two years.

<table>
<thead>
<tr>
<th>Measured variable</th>
<th>2001</th>
<th>2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residue cover</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(kg/ha)</td>
<td>1106</td>
<td>3190</td>
</tr>
<tr>
<td>canola</td>
<td>1042</td>
<td>3259</td>
</tr>
<tr>
<td>wheat</td>
<td>1846</td>
<td>3065</td>
</tr>
<tr>
<td>pea</td>
<td>3190</td>
<td>3259</td>
</tr>
<tr>
<td>Soil moisture content</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 - 50 mm (%)</td>
<td>16.4</td>
<td>9.8</td>
</tr>
<tr>
<td>50 - 100 mm (%)</td>
<td>20.6</td>
<td>21.9</td>
</tr>
</tbody>
</table>

Results and Discussion

Residue cover
In 2001, the canola and wheat residue plots had a similar level of residue (Table 2), although wheat is normally classified as a high residue-producing crop. The pea residue plots had higher residue covers in that year. Higher residue covers were observed in 2002, and similar levels of residue cover were observed for all residue types in that year.

Soil moisture content
In the 2001 seeding season, gravimetric soil moisture content (16.4%) at the depth of 0-50 mm was adequate (Table 2), while in 2002, the soil moisture content (9.8%) was quite low. The low rainfall in 2002 (Table 1) contributed to this low soil moisture content. Adequate soil moisture content at the 50-100 mm soil layer was observed in both years.

Soil cone index
The values of soil cone index generally increased with an increase in soil depth, and the overall cone index was low in the seedbed layers (0-40 mm) (Fig. 3). In 2001, the canola residue plots had the highest cone index followed by the wheat residue and pea residue plots (Fig. 3a). This shows that pea as a previous residue resulted in less compacted or soft soil. In 2002, a similar trend of residue type effects on the soil cone index was observed, although there was little difference in cone index between the residue types (Fig. 3b). Francis et al. (1987) reported that soil strength increases as the soil dries. The drier soil condition in 2002 may explain the lack of differences in cone index between the residue types (Fig. 3b). The drier soil condition in 2002 may explain the lack of differences in cone index between the residue types (Fig. 3b). In both years, the cone indices above the 80 mm depth inside the wheel track (Fig. 3c) were higher than those outside the wheel track (Fig. 3d), indicating that the tractor traffic from the seeding operation caused some soil compaction.

Effect of residue and opener types
Mean seeding depth
In both years, canola was seeded at the higher limit of the range of seeding depth (13-38 mm) recommended by Manitoba Agriculture, Food, and Rural Initiatives for canola (Fig. 4). The interaction effect of residue and opener types was significant in both years. In the normal seeding conditions observed in 2001, the pea residue plots seeded with disc
Fig. 4. Seeding depth for the different combinations of three residue types and two opener types in two years. Values with the same letters within each year are not significantly different at P < 0.1 according to Duncan’s multiple range test.

had the greatest depth, followed by the same residue seeded with hoe. Smaller seeding depths were observed for the wheat residue plots and the smallest seeding depths were observed for the canola residue plots, regardless of the opener type. This trend is correlated with the opposite trend of the soil cone index (Fig. 3a). This result also agrees with the finding by Chen et al. (2004c) that soft soil enhances seeding depth.

In the dry soil conditions observed in 2002, differences in seeding depth were less pronounced between the combinations of residue and opener types. Values of soil cone indices (Fig. 3b) were only slightly different between the residue type treatments, which was apparently not enough to make a difference in seeding depth. Again this was a result of the dry soil conditions at the seeding time of that year. In 2002, a different trend was observed, where seeding on canola and wheat residues with disc gave greater seeding depth than the other treatments. In both years, disc resulted in a greater seeding depth under each crop than hoe opener.

Seed scattering index The standard deviation of mean seeding depth has been used as the seed scattering index (Tessier et al. 1991; Chen et al. 2004a), as it represents the vertical scattering of seeds around the mean of the seeding depth. A lower seed scattering index means a more uniform seeding depth. Interaction effects of opener type and residue type were not significant. Hoe opener had a seed scattering index of approximately 2.5 mm, in both years, while disc opener had a 38% lower seed scattering index in 2001 and a 25% greater seed scattering index in 2002 (Fig. 5a). The inconsistent effect of disc opener on seed scattering index was likely due to the differences in soil moisture content and residue cover between these two years. The dry soil conditions in 2002 may have caused the changes in the penetration depth of the disc opener, which enhanced the vertical scattering of the seeds.

The effect of residue type on the seed scattering index was consistent for two years, whereas the seed scattering indices for pea residue were 32-56% lower than those for wheat residue and canola residue (Fig. 5b). The soft ground condition of pea residue favoured a more uniform seed placement. The results also show that wheat residue resulted in a more uniform seeding depth than canola residue, which was, however, not statistically significant due to the high variation of the data.

Speed of crop emergence The type of opener played a significant role in the speed of crop emergence (Table 3). Disc opener showed an average of 68 and 36% faster emergence rate than hoe opener in 2001 and 2002, respectively. In 2001, the trend of the effect of residue type on the speed of crop emergence was: pea residue > wheat residue > canola residue. This observation may be explained by the trend of the soil cone (Fig. 3a) and seed scattering indices (Fig. 5b) in that year, indicating that the soft soil and uniform seed placement promoted plant emergence, despite deeper seeding depth of the pea residue plots.

In 2002, the extremely high speed of crop emergence in canola residue was due to the vast amounts of volunteer canola that started to grow in and between the

### Table 3. Rate of canola emergence (plant d−1 m−2) in two years.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2001</th>
<th>2002</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Opener</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disc</td>
<td>23.6a*</td>
<td>12.9</td>
</tr>
<tr>
<td>Hoe</td>
<td>14.0b</td>
<td>8.2</td>
</tr>
<tr>
<td>Residue</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canola</td>
<td>17.4b</td>
<td>11.2</td>
</tr>
<tr>
<td>Wheat</td>
<td>18.3ab</td>
<td>12.4</td>
</tr>
<tr>
<td>Pea</td>
<td>21.3a</td>
<td>10.9</td>
</tr>
</tbody>
</table>

*Values with the same letters within each column and treatment factor are not significantly different at p < 0.1 according to Duncan’s multiple range test.
Table 4. Plant populations of canola (plants/m²) in two years.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2001</th>
<th>2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canola-Disc</td>
<td>62b**</td>
<td>Opener</td>
</tr>
<tr>
<td>Wheat-Disc</td>
<td>50c</td>
<td>Disc</td>
</tr>
<tr>
<td>Pea-Disc</td>
<td>70b</td>
<td>Hoe</td>
</tr>
<tr>
<td>Canola-Hoe</td>
<td>74b</td>
<td>Residue</td>
</tr>
<tr>
<td>Wheat-Hoe</td>
<td>103a</td>
<td>Canola</td>
</tr>
<tr>
<td>Pea-Hoe</td>
<td>112a</td>
<td>Wheat</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pea</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mean*</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>123a</td>
<td>112</td>
</tr>
<tr>
<td>109a</td>
<td>113</td>
</tr>
<tr>
<td>238a</td>
<td>152</td>
</tr>
<tr>
<td>77b</td>
<td>55</td>
</tr>
<tr>
<td>73b</td>
<td>46</td>
</tr>
</tbody>
</table>

* The coefficient of variation was 55%.
** Values with the same letters within each column and treatment are not significantly different at p < 0.1 according to Duncan’s multiple range test.

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2.34 LE GÉNIE DES BIOSYSTÈMES AU CANADA DOAN, CHEN and IRVINE
REFERENCES


