Soil Temperature and Direct Seeding

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May 2005

Introduction

Direct seeding is a conservation practice system, and its benefits are well known worldwide. A characteristic of direct seeding is that it retains most of the crop residues on the soil surface. Crop residue insulates the soil and slows the rate at which thermal energy is exchanged between the soil and the atmosphere, and it results in slightly cooler soil temperatures. This cooler soil temperature has the potential to slow plant germination and emergence.

The effect of cooler soil temperature on plant germination and crop emergence in direct seeding systems has been well documented for Manitoba and Saskatchewan; however, there was little or no information available for Alberta before 1996.

Field experiments were conducted from 1996 to 1998 in black chernozemic soils at Fort Saskatchewan and Red Deer to evaluate soil temperature, seedbed moisture and crop emergence under direct-seed and conventional-till systems. This fact-sheet summarizes the major findings of this study and the implications for growers.

Major Findings

Fort Saskatchewan

In most cases, the direct-seed plots cooled more slowly and remained warmer during winter. The reverse, however, happened in spring; during the pre-seeding soil-warming period, the direct- seed plots warmed more slowly than the conventional-tilled ones and remained slightly cooler until seeding. During the post-seeding period, direct-seed plots tend to be slightly cooler than conventional-tilled plots.

Winter Soil Temperature — in all three years from 1996 to 1998, tillage treatments had a significant effect on soil temperature at both 2 and 5 cm depths. The mean soil temperature at these depths during winter in direct seeded plots was generally warmer than in conventional-till plots. In 1996, the daily mean, maximum and minimum temperatures of direct- seed plots were at least 1.8 ˚C warmer than the conventional-till ones. However, in 1997, this warming effect was marginal at the 2 cm depth, and there were no significant differences in temperature at the 5 cm depth. In 1998,the daily mean, maximum and minimum temperatures at the 2 cm depth were at least 0.5 ˚C warmer in the direct-seed plots than the conventional-till ones (Table 1).

Pre-seeding Soil Temperature—in 1996 and 1998 tillage treatments had a significant effect on soil temperature at the 2 cm depth; but in 1997, there were no differences in soil temperature between direct-seed and conventional-till plots. There was even less tillage effect on soil temperature at the 5 cm depth; only in 1996 was a significant effect noted. In 1996 and 1998, the daily mean temperature of conventional-till plots at both 2 and 5 cm was at least 0.7 ˚C higher than in the direct-seed plots, and in both conventional and direct-seed plots, the 2 cm depth was warmer than the 5 cm depth. In general, the mean temperature of the conventional-till plots at 5 cm was approximately equivalent to the temperature at the 2 cm depth in the direct-seed plots. The daily maximum and minimum soil temperature in the spring showed similar differences between the conventional-till and direct-seed plots. There were some differences in the warming rate at which soil temperatures reached the critical 5 ˚C that would permit crop germination. The soil-warming rate at 2 and 5 cm depths was greater in conventional-till plots than for the direct-seed plots (Table 2). The data presented here suggest that the slightly cooler soil temperatures of direct-seed production systems can be compensated for by shallower seeding i.e. 2 cm as opposed to 5 cm.

Table 1. Effect of tillage treatments on soil temperature at Fort Saskatchewan—winter period

Tillage treatment	Soil temperature					
	Daily mean		Daily maximum		Daily minimum	
	2 cm	5 cm	2 cm	5 cm	2 cm	5 cm
Winter 1996: January 14 – 30						
Conventional	- 10.8	- 9.8	- 9.0	- 8.1	- 13.0	- 12.0
Direct-seed	- 8.5	- 7.9	- 6.9	- 6.3	- 10.8	- 10.1
Significance						
Tillage treatment	***	***	***	***	***	***
Winter 1996-97: November 17 – January 12						
Conventional	- 2.5	- 2.2	- 1.5	-1.2	- 3.7	- 3.3
Direct Seed	- 2.2	- 2.1	- 1.3	- 1.2	- 3.4	- 3.2
Significance						
Tillage treatment	**	ns	*	ns	*	ns
Winter 1997-98: December 16 – January 13						
Conventional	- 5.5	- 5.1	- 3.9	- 3.6	- 7.2	- 6.8
Direct seed	- 4.7	- 4.5	-3.2	- 3.2	- 6.3	- 6.2
Significance						
Tillage treatment	***	ns	***	ns	***	ns

***, **, * Significant at P= ≤ 0.01, P = ≤ 0.05 and P = ≤ 0.1, ns = non-significant, , respectively.

Table 2. Effect of tillage treatments on soil temperature at Fort Saskatchewan—prior to seeding (soil warming phase)

Tillage treatment	Soil temperature							
	Daily mean		Date daily mean would reach 5 ˚C		Daily maximum		Daily minimum	
	2 cm	5 cm	2 cm	5 cm	2 cm	5 cm	2 cm	5 cm
1996: March 25 – May 3, 1996								
Conventional	1.9	1.1	April 22	April 25	6.2	4.3	- 2.0	- 1.9
Direct seed	1.1	0.2	April 26	May 1	4.2	2.7	- 1.9	- 2.3
Significance								
Tillage treatment	***	**	***	*	***	***	ns	*
1997: April 6 – May 13, 1997								
Conventional	5.0	4.2	April 25	April 27	9.6	7.6	0.5	0.6
Direct seed	4.9	4.1	April 25	April 27	10.0	7.5	0.1	0.5
Significance								
Tillage treatment	ns	ns	ns	ns	ns	ns	ns	ns
1998: April 18 – May 3								
Conventional	8.6	8.0	April 18	April 19	13.5	12.9	3.3	3.3
Direct seed	7.8	7.3	April 19	April 20	11.8	11.0	3.3	3.3
Significance								
Tillage treatment	***	ns	***	ns	***	ns	ns	ns

***, **, * Significant at P= ≤ 0.01, P = ≤ 0.05 and P = ≤ 0.1, ns = non-significant, respectively.

Post-seeding Soil Temperature—in 1996 and 1997 following seeding, daily mean, maximum and minimum soil temperatures were slightly higher in conventional-till plots as compared to direct-seed plots, however, with the exception of the daily mean soil temperature at the 5 cm depth, none of these differences were significant (Table 3). Although there were no statistically significant differences in soil temperatures between the seed-row versus within the seed rows, the actual soil temperatures were marginally higher between the seed-rows than within them. (Table 3)

Table 3. Effect of tillage treatments on soil temperature at Fort Saskatchewan — post-seeding period.

Tillage treatment	Soil temperature					
	Daily mean		Daily maximum		Daily minimum	
	2 cm	5 cm	2 cm	5 cm	2 cm	5 cm
1996: May 16 – June 5						
Conventional tillage	13.4	12.7	19.0	16.8	8.2	8.6
Direct seed (DS)	12.7	11.6	18.4	15.4	7.3	7.8
DS: between seed-rows	13.2	12.4	19.2	16.7	7.6	8.1
DS: within seed-rows	12.9	11.9	18.2	15.6	7.8	8.2
Significance						
Tillage treatments	ns	*	ns	ns	ns	ns
Between seed-row vs. within seed-row	ns	ns	ns	ns	ns	ns
1997:May 22 – June 11						
Conventional tillage	15.9	15.5	21.8	20.2	10.7	11.1
Direct seed (DS)	15.4	15.3	20.6	19.8	10.8	11.0
DS: between seed-rows	15.8	15.4	21.2	20.0	10.8	11.0
DS: within seed-rows	15.6	15.4	21.2	20.0	10.6	11.0
Significance						
Tillage treatments	ns	ns	ns	*	ns	ns
Between seed-row vs. within seed-row	ns	ns	ns	ns	ns	*

***, **, * Significant at P= ≤ 0.01, P = ≤ 0.05 and P = ≤ 0.1, ns = non-significant, respectively.

Seedbed Soil Moisture—seedbed soil moisture was slightly higher in direct-seed plots as compared to conventional-tilled plots (Table 4).

Table 4. Seedbed Moisture – Fort Saskatchewan 1997 - Soil Moisture at 5 cm depth

Tillage treatment	June 4 – 17		June 26 – July 7	
	Mean	Change/day	Mean	Change/day
Conventional	22 mm	- 0.5 mm	21 mm	- 0.6 mm
Direct seed	23 mm	- 01 mm	21 mm	- 0.5 mm
Standard error	0.4	0.1	0.4	0.05
Significance	*	ns	ns	ns

P = ≤ 0.1, ns = non-significant, respectively.

Plant Emergence—crop emergence and early growth under direct seeding were delayed during the first three weeks following seeding; after that, the differences began to disappear, and the final plant counts were higher in direct-seed plots as compared to conventional-till plots. (Table 5).

Table 5. Plant emergence of spring wheat in 1996 – Fort Saskatchewan

Tillage treatment	Plants per meter row			
	May 29	June 6	June 12	June 24
Conventional	183	170	170	158
Direct seed	158	180	212	195

Red Deer

Pre-seeding Soil Temperature— Similar to Fort Saskatchewan, during the pre-seeding soil-warming period, conventional-till plots had higher temperatures compared to direct-seed plots. Crop residue levels had a significant effect on the soil temperature. The direct-seed plots with high crop residues were significantly cooler than the direct-seed plots with low crop residue levels. There were no significant differences in daily mean soil temperature between the conventional-till plots and the direct-seed plots with low crop residue levels (Table 5). This data suggest that the amount of crop residue on the soil surface is a major factor in soil warming process during pre-seed period. The daily mean soil temperatures are 2-3 ˚C cooler under thick layer of residues as compared to thin residues.

Table 5. Effect of tillage treatments and crop residue on soil temperature at Red Deer - spring warming period

Treatments	Soil Temperature							
	Daily Mean		Date daily mean would reach 5 ˚C		Daily Maximum		Daily Minimum	
	2 cm	5 cm	2 cm	5 cm	2 cm	5 cm	2 cm	5 cm
1998: March 11 – May 5								
Conventional (C)	6.6	6.0	April 3	April 5	15.4	12.4	0.6	1.4
Direct seed: high residue (DSH)	1.9	1.4	April 14	April 19	4.8	3.0	0.0	0.2
Direct seed: low residue (DSL)	5.3	4.2	April 7	April 11	10.7	7.5	0.4	1.1
Contrasts and significance								
C vs. Direct Seed	*	*	*	*	*	**	ns	**
C vs. DSH	*	**	**	**	**	**	*	**
C vs. DSL	ns	*	ns	*	*	*	ns	**
DSH vs. DSL	*	*	**	**	*	*	ns	**

***, **, * Significant at P= ≤ 0.01, P = ≤ 0.05 and P = ≤ 0.1, ns = non-significant, respectively.

Post-seeding Soil Temperature— following seeding, at 2 cm depth only, the daily mean soil temperatures in conventional-till plots were about 1 ˚C warmer than in direct-seed plots with high crop residues. There were no soil temperature differences between conventional–till plots and direct-seed plots with low crop residues (Table 6).

Table 6. Effect of tillage treatments and crop residue on soil temperature - post-seeding period

Treatment	Soil temperature							
	Daily mean		Daily maximum		Daily minimum		Daily range	
	2 cm	5 cm	2 cm	5 cm	2 cm	5 cm	2 cm	5 cm
1997: May 20 – June 9								
Conventional	13.4	13.0	19.3	16.8	8.8	9.5	10.5	7.2
Direct seed: high residue	12.4	12.2	16.2	15.2	9.2	9.6	7.0	5.6
Direct seed: low residue	13.5	13.0	20.2	17.3	8.4	9.3	11.8	8.0
Contrast and significance								
Conventional (C) vs. Direct seed (DS)	**	ns	ns	ns	ns	ns	ns	ns
C vs. DS High residue	**	*	*	*	ns	ns	*	*
C vs. DS low residue	ns	ns	ns	ns	ns	*	ns	ns
DS High residue vs. DS low residue	**	*	*	**	*	*	*	**

***, **, * Significant at P= ≤ 0.01, P = ≤ 0.05 and P = ≤ 0.1, ns = non-significant, respectively

The cooler soils under direct seeding are mainly due to the crop residue layer on the soil surface. Thicker residue layers result in cooler soils during the spring. Crop residue reflects sunlight and insulates the soil from the air, and thicker layers provide better insulation. While this crop residue protects direct-seed soils from extreme seasonal temperature changes, it also slows spring warming.

Moist soils warm more slowly than dry soils, and direct-seed soils are usually moister than conventional-tilled soils, especially at the surface. The increased moisture is a result of the residue layer that reduces evaporation from the soil. As well, the standing stubble contributes to higher soil moisture by trapping snow and reducing wind speed for reduced evaporation.

In the spring, the soil is warmest near the surface, which is very important for direct seeding. The data from both Fort Saskatchewan and Red Deer show that much of the heat advantage for seeding obtained with conventional tillage at 5 cm depth can be offset by seeding shallower when direct seeding. The higher near-surface soil moisture levels under direct seeding are critical for making shallow seeding viable. In the spring, the soil is warmest near the surface, which is very important for direct seeding.

Soil Temperature and Crop Growth

Seed of most major crops grown in Alberta (cereals, Argentine canola, pulses) begins to germinate at temperatures as low as 3 to 5°C. Polish canola is the exception; it starts to germinate at about 5°C but usually requires a seedbed of about 7 to 10°C for a healthy stand. Soil temperature is an important factor in crop germination and establishment. If soil temperature at the planting time is too cool, germination is delayed, resulting in uneven emergence.

Germination and seedling growth are variable and slow at low soil temperatures. As temperature increases, germination and emergence become faster and more uniform. Generally, emergence time halves for every 5°C increase between 5 and 20°C. Percent emergence is also usually higher on warmer soils.

Crop maturity may also be delayed depending on summer growing season conditions. Although yields may be lower in some years, research shows that on average, over the long term, direct seeding yields are as high or higher than conventional tillage yields under most conditions (Table 7). Delayed emergence and maturity are a greater concern in areas with a very short growing season. In this study, improved yields under zero tillage were attributed to increased soil moisture in drier years.

Table7. Yield comparisons between conventional, minimum and zero tillage from trials conducted in western Canada

Location	Soil zone	Year	Tillage system			Zero-till advantage (%)	Reference
			Conventional	Minimum	Zero		
			--------------- Yield (Bu/ac) -------------				
Wheat (Spring)							
Coronation, AB	Dark Brown	1986 - 90	25.5 [a]	27.3[b]	31.4[c]	19	Jans et al. 1991
Indian Head, SK	Thin Black	1987 - 90	37.9 [a]	39.2 [a]	37.9 [a]	0	Lafond et al. 1992
Indian Head, SK	Thin Black	1987- 90	23.2 [a]	28.2 [b]	28.0 [b]	17.1	Lafond et al. 1992
Wheat (Winter)							
Indian Head, SK	Thin Black	1992	30.3	32.0	31.0	2.3	Lafond et al 1992
Barley							
Rycroft, AB	Grey	1989 - 90	25.1[a]	29.0 [a]	26.0[a]	3.4	Arshad et al 1995
Alliance, AB	Dark Brown	1989 - 92	68.1[b]	71.9[b]	79.1[a]	13.9	McAndrew et al 1994
Elk Point, AB	Grey	1989 - 92	47.7[a]	48.5[a]	47.4 [a]	0.0	McAndrew et al 1994
Hairy Hill, AB	Black	1989 - 92	63.0[a]	63.1[a]	65.2[a]	3.4	McAndrew et al 1994
Plamondon, AB	Grey	1989 - 92	62.5[a]	56.6[a]	63.7[a]	1.9	McAndrew et al 1994
Wainwright, AB	Thin Black	1989 - 92	75[b]	73.0[b]	79.3[a]	5.4	McAndrew et al 1994
Canola							
Rycroft, AB	Grey	1989 -90	10.5 [b]	14.5 [c]	11.1 [b]	5.3	Arshad et al 1995
Field peas							
Indian Head, SK	Thin Black	1987 - 90	29.0[a]	28.3[a]	32.0 [b]	10.3	Lafond et al 1992

Numbers with different letters are statistically different

Recommendations for Seeding into Cold Soils for a Healthy Crop Stand

Along with soil temperature, several other factors influence crop growth, such as seeding depth, crop residue management, disease and seed quality. For healthy crop stands under direct seeding follow these tips:

- **Residue Management**— the results from Red Deer suggest that, in direct seeding, the thickness of residue layer on the soil surface is a major factor in the soil warming process. Successful crop residue management can be achieved by ensuring an even spread of chaff and chopped straw so that seeding equipment does not plug in areas with heavy crop residues, soil warms more evenly, and hair-pinning is reduced. (See also: *Equipment Issues in Crop Residue Management for Direct Seeding* Agdex 519-4 and *Residue Management for Successful Direct Seeding*, Agdex 570-4).
- **Crop Rotation**—rotate high residue wheat and barley with low residue crops such as canola, peas and lentils. Avoid high residue crops the year after high residue crops.
- **Seed Quality**—use certified seed with high germination and seedling vigor, and treat the seed to minimize the seed and soil borne disease concerns.
- **Seeding Depth**—in direct seeding systems, spring soil temperatures are warmer at shallower depths. There are also better soil moisture conditions near the surface, therefore seed as shallowly as possible without compromising the seed integrity.
- **Seed Openers**—in direct seeding systems, seeding with hoe or knife openers that pushes the crop residue off the furrows results in warmer spring soil temperatures. Research at the Red Deer site has shown that under heavy crop residue situations, seeding with hoe openers (Stealth – narrow hoe style) resulted in warmer soil soils than seeding with disc type openers (Barton—narrow row disc style).
- **Fertilizer Placement**—use safe rates of seed-placed fertilizer; consider equipment that separates the seed and fertilizer (See *Alberta Fertilizer Guide*, Agdex 541-1, and Ground Opener Systems, Agdex 519-24, for more information.

Conclusion

Research has shown that soil temperature, while cooler under direct-seed soils, does not appear to be a concern in most years. Cooler seedbeds can be managed through even spreading of crop residues and shallower seeding.

Reference

Froebel, B and A. Howard. 1999. Soil Temperatures and Direct Seeding. Alberta Agriculture, Food and Rural Development. Agdex 590-2
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