Moisture Management as Affected by Tillage System

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Abstract

Low disturbance direct seeding, commonly known as zero tillage, has many advantages including reducing soil erosion and enhancing soil moisture status. Zero tillage conserves moisture by trapping more snow and by reducing losses of water due to evaporation. Both of these impacts are related to the height of the stubble with crops such a dry pea having very little snow trap and limited reduction in evaporation by due to reduction in wind speed. Evaporation from the soil surface occurs primarily from the top 15 cm so duration of moisture conservation from small showers is significantly larger under zero tillage than conventional tillage. High levels of surface residues are important in slowing run off and reducing soil erosion by water. However, if the soil profile is full near the surface and water is frozen in the macropores during a rapid spring thaw run off will still happen at a high rate. The ability of a soil to conserve water may be especially critical on light textured soils since these soils not store significant amounts of water regardless of the tillage system used. Since light textured soils have high infiltration rates the major impact of zero tillage on these soils will be improved seedling establishment by limiting the drying of the seedbed as well as the reduction in wind speed by the standing stubble. In years such as 1998, where soil moisture is extremely low, there is insufficient plant available water to produce significant yield regardless of the tillage system.

However, the impact of improve moisture conservation on final grain yield is not always consistent since many other factors impact this result, not the least of which is seeding date. In regions with heavy snowfall and heavy soils zero tillage can sometimes delay planting due to wet soil conditions and in some years this may result in delaying flowering and maturation of the crop into a period where high temperatures and/or drought may limit the ability of the crop to complete grain filling. Weed control is critical in any cropping system and early removal of weeds is critical to good yields regardless of the cropping system.

This presentation will outline the direct and indirect impacts of direct seeding and present yield information from across the Northern Great Plains indicating that zero tillage has the greatest positive yield impacts in locations where there is a high potential for significant negative moisture status early in the development of the crop.

Direct effects of zero tillage

Improved soil moisture due to snow trapping

Standing stubble collects and retains snowfall and in many areas can increase preseeding soil moisture levels by 20-30 mm (Lafond 1992). In areas where there is adequate snowfall the amount of water trapped in the stubble is directly related to the height of the stubble and since crops such as dry pea trap very little snow and they contribute little more moisture than conventional tillage.

Improved infiltration rate

Infiltration rate and cumulative infiltration followed the trend no till+straw >till+straw >till with straw removed (Singh et al 1996). The impact of straw removal was much larger than the impact of tillage per se and the implication of this would be that direct seeding will likely have a greater positive impact on this trait in rotations where straw is removed or crops rotations which produce very little residue. While zero tillage had higher ponded infiltration rates on silt loam and sandy loam soils in northern Alberta the impact of soil type was larger than that of tillage (Azooz and Arshad 1996). Infiltration rates declined as

soils approached near saturated conditions but direct seeded plots had the highest rates under all moisture conditions. There were significant differences in rate of infiltration based on time of the year when sampling occurred. The overall improvement in infiltration after fifteen years of direct seeding would allow greater intake of water when soils were dry and thus less potential for runoff and water loss into depressional areas of fields during short term intense precipitation events.

Reduced rate of soil drying and potential evaporation due to standing stubble

Research in the semiarid Brown soil zone near Swift Current has shown that when combination with direct seeding, tall stubble (35 cm or taller) increases yields by reducing evapotranspiration as the crop grows (Cutforth and McConkey 1997). In that study the treatments were deployed immediately before seeding on plots that had overwintered with tall stubble. Seeding wheat into tall stubble increased grain yield but growing season evapotranspiration was not affected by stubble height. Based on their results, the authors recommended that producers in the semiarid prairies seed spring wheat directly into stubble left standing as tall as practical (at least 30 cm). In the Brandon area, yields were not increased by seeding into tall stubble (Volkmar per com). Thus the impact of tall stubble appears to be related to the potential reduction in wind speed and thus evapotranspiration.

Indirect impacts of zero tillage

Altered weed numbers and timing of weed emergence

The development of canola genetics with novel herbicide tolerance has enabled direct seeding to be adopted over a wide range of conditions where weed management issues previous limited direct seeding of canola. This change has enabled the widespread adoption of direct seeding since canola is a major crop in the Black soils of the prairies. Zero tillage has a number of impacts on weed pressure. In general the total numbers of weeds decrease under direct seeding but this assumes good management is possible with herbicides. Weed destruction from weathering and predation is greater when the weeds are on the surface. Seed loss from predation is greater with large seeds as they are easier for insects and birds to find. With the exception of wild mustard and red root pigweed conservation tillage promoted earlier emergence than conventional tillage (Bullied and Van Acker 2003). Over the years 1997-2001 fall application of nitrogen using narrow points or seeding with sweeps in the spring resulted in weedier plots in the Brandon area. In a trial conducted at Indian Head from 1987-1998, zero tillage was weedier in wet springs regardless of fall conditions (Derksen Per com). Conventional tillage was weedier when a dry spring was preceded by dry fall conditions. Minimum tillage was weedier when a dry spring was preceded by a wet fall. In general weediness was greater when a wet year followed dry years. These observations are likely explained by differences in soil moisture and thus conditions for germination.

Disease impacts of zero tillage

Direct seeding reduced root diseases severity of cereals but increased leaf spot severity (Bailey 1996). In years where leaf spot diseases were prevalent conventional tillage crops had a 6% yield advantage over zero tillage due to these infections but a 5% lower yield due to root rots. Thus the net impact of disease on crop yields at Indian Head was close to zero. Weather and crop rotation were more important than tillage in managing crop disease. Bailey (1996) summarizes several studies indicating that burial of sclerotia of *Sclerotinia sclerotiorum* for an extended period of time will reduce the survival of sclerotia and thus limit inoculum. A similar strategy has been recommended for control of blackleg. Unfortunately deep tillage or ploughing would be required and could result in significant soil erosion. During the years 1994-1998 reduced tillage did not increase foliar diseases in barley, wheat or canola (Bailey et al 2000). Foliar diseases of cereal grains in this trial were more strongly influenced by crop rotation and weather conditions than by tillage. The sclerotinia and blackleg impacts were of tillage were limited in this trial and in recent work conducted at Brandon.

Crop yield may not always be increased

Crop yields in various areas of the north eastern Great Plains vary in response to zero tillage and with the years in which trials are conducted. Time savings and reduction in soil erosion are significant benefits to direct seeding and thus these systems may be more profitable without positive yield impacts.

Brandon

In a trial comparing crop rotation and impacts on the management of wild oats it was found that there were large differences in crop yields which were related to control of perennial weeds, in particular dandelion (Table 1). This trial included a standard spring wheat, canola, spring wheat, pea rotation and a silage/millet, canola, silage/millet, pea rotation. The silage crop grown was winter triticale or fall rye followed by a crop of millet seeded in Mid June after the silage was harvested. In 2002 and 2003 dry pea yields were much higher on zero tillage after spring wheat than when minimum tillage (a single spring cultivation) preceded pea. This was not the case after silage and since the silage treatments were double cropped it is unlikely that there were differences in spring soil moisture. The indirect impacts of weed management were larger than the direct impact of soil moisture between zero tillage and minimum tillage.

There were no differences in the yield of spring wheat in Sw-can-Sw-pea rotation. (Table 2). While there were significant differences in pea yield spring wheat yields were similar. If high disturbance direct seeding or minimum tillage is used fall control of perennial weeds will be required and given that higher numbers of annual weeds often occur after tillage it will be even more critical to have timely in crop weed management.

Table 1. Impact of tillage and crop rotation on pea yields at Brandon (Derksen unpublished)

	SW-can-SW-pea		Sil-can-Sil-pea	
year	MT	ZT	MT	ZT
2001	3074	3165	3398	3448
2002	2034	2837	2203	2313
2003	1497	2124	2728	2728

sil=silage of winter cereals followed by a crop of millet
SW=spring wheat
pea= dry pea
can=Canola^{RR}

Table 2. Impact of tillage and crop rotation on wheat yields at Brandon (Derksen unpublished)

	SW-can-SW-pea	
year	MT	ZT
2000	3078	3098
2001	1709	1671
2002	1802	1816
2003	2351	2149

sil=silage of winter cereals followed by a crop of millet
SW=spring wheat
pea= dry pea
can=Canola^{RR}

Red River Valley

The Red River valley of Manitoba has a lower moisture deficit than South Western Manitoba and thus positive yield responses to zero tillage have been less common. Flax yields have been greater under direct seeded conditions in the Morden area (Dave McAndrew per communication). However, heat loving crops such as dry bean and soybean often have reduced yields in this area of the province when seeded using zero tillage (Table 3). Delayed seeding due to wet soil conditions is unlikely for dry bean and soybean since they are planted late due to their sensitivity to frost. However, if seeding of cool season crops is delayed yields of cereal grains, dry pea and oilseed crops are generally reduced due the higher temperatures which later seeded crops encounter. While delaying seeding will not reduce crop yields in every season due to the erratic nature of rainfall; research and Manitoba Crop Insurance data both support the general conclusion that delayed seeding reduces crop yields. In addition, late harvests are more difficult due to cool short days in the later part of the season.

In the Carman/Portage area of the province grain yields of pea, canola and spring wheat were unaffected by tillage system (Borstlap and Entz 1994). Tillage had a limited impact on dry matter accumulation. There was a slightly improved ET efficiency which was attributed to lower evaporation from ZT.

Table 3. Impact of tillage and residue management on dry bean yield at Morden (Dave McAndrew personal communication)

Tillage/residue mgt	Plants m^{-2}	Days to flowering	Days to 90% brown pods	Yield kg ha^{-1}	500 ml weight
1. Zero Till	13.3 c	48.3 c	94.7 d	2107 b	410 a
2. Zero Till-Fall burn	15.7 ab	47.5 b	92.5 bc	2241 a	408 ab
3.Zero Till-Spring burn	14.6 b	48.1 c	93.6 cd	2284 a	410 a
4.Fall+Spring Tillage	16.3 a	46.8 a	90.5 a	2307 a	407 b
5.Spring Tillage	15.1 ab	46.9 a	91.8 b	2218 a	406 b

Indian Head

During the period 1987-1998 several crop rotations were compared at Indian Head. An economic analysis of these trials indicated that costs increased with cropping intensity and cropping diversity but these costs were not affected by tillage method (Zentner et al 2002). Over a range of prices mixed rotations had the highest net returns and economic returns were greater under minimum or zero tillage management. In this study spring wheat on pea stubble was had higher yields than spring wheat on spring wheat stubble (Table 4). However, there was no difference in spring wheat yields between conventional and zero tillage on pea stubble whereas when wheat was planted on wheat stubble there was an advantage to zero tillage. This advantage is attributed to increased soil moisture.

Table 4. Impact of tillage system and rotation on crop yields at Indian Head!

		Tillage system			CT vs
Crop	Stubble	CT	MT	ZT	ZT & MT
Spring wheat	wheat (spring & winter)	2044	2214	2178	**
Spring wheat	pea	2418	2499	2303	NS
Pea	wheat (winter)	2272	2407	2450	*
Flax	wheat (spring)	22272	2407	2450	*

! From Zenter et al 2002

Melfort

During the years 1994-1998 zero tillage and minimum tillage yields were equal for barley, wheat and pea (Bailey et al 2000). In one season barley under conventional tillage had lower yields but the overall mean yields did not differ. While canola yields were not statistically different zero tillage yields were higher in one season.

Mandan, North Dakota

In a twelve year study, spring wheat yields were generally enhanced by the use of minimum and zero tillage systems (Halvorson et al 2000). Conventional tillage in this trial was a spring discing and minimum tillage was under cut at 7.5 cm. In years when total available plant water was greater than 260 mm but less than 400 mm wheat yields were greater with no tillage. In seasons where total plant available moisture was greater than 400 mm crop yields were greater under conventional tillage (medium nitrogen rates). When moisture levels were low there was little impact of tillage system on grain yields. In this trial there was no evidence of poor establishment resulting from rapid drying of the seedbed due to tillage.

When is low disturbance direct seeding most likely to increase crop yields?

- Relatively dry climatic area with high levels of potential evaporation or in a moist area when these conditions occur in the early part of the growing season.
- Tall dense stubble
- Adequate snowfall to fill the stubble
- Fertilizer placement is done in a manner with limits or prevents damage during crop establishment.
- Frequent precipitation events rather than a limited number of major events
- Weed and disease control is at a level equal to or greater than conventional tillage

References

Azooz, R. H and Arshad, M.A. 1996. Soil infiltration and hydraulic conductivity under long-term not-tillage and conventional tillage systems. Can. J. Soil Sci. 76:143-152

Bailey, K.L. 1996. Diseases under conservation tillage systems. Can. J. Plant Sci. 76:635-639.

Bailey, K.L. Johnston, A.M., Kutcher, H.R., Gossen, B.D, and Morrall, R.A.A. 2000. Can. J. Plant Sci. 80:169-175.

Borstlap, S. and Entz, M. 1994. Zero-tillage influence on canola, field pea and wheat in a dry subhumid region: Agronomic and physiological responses. Can. J. Plant Sci. 74:411-420.

Bullied, W. J. and Van Acker, R. C. 2003. Conventional-and conservation-tillge systems influence emergence periodicity of annual weed species in canola. Weed Science 51:886-897.

Cutforth, H.W. and McConkey, B.G. 1997. Stubble height effects on microclimate, yield and water use efficiency of spring wheat grown in a semiarid climate on the Canadian Prairies. Can. J. Plant Sci. 77: 359-366.

Halvorson, A. D. Black, A. L., Krupinsky, J. M, Merrill, S. D., Wienhold, B. J. and Tanaka, D. L. 2000. Spring wheat response to tillage and nitrogen fertilization in rotation with sunflower and winter wheat. Agron. J. 92:136-144.

Lafond, G.P., Loeppky, H. and Derksen, D.A. 1992. The effects of tillage systems and crop rotations on soil water conservation, seedling establishment and crop yield. Can. J. Plant Sci. 72: 103-115.

Lafond, G.P., Boyetchko, S.M., Brandt, S.A., Clayton, G.W. and Entz, M.H. 1996. Influence of changing tillage practices on crop production. Can. J. Plant Sci. 76:641-649.

Singh, B., Chanaskyk, D.S. and McGill, W.B. 1976. Soil hydraulic propteries of an Othic Black Chernozem under long-term tillage and residue management. Can. J. Soil Sci. 76:63-71.

Zenter, R. P., Lafond, G.P., Derksen, D.A. and Campbell, C. A. 2002. Tillage method and crop diversification: effect on economic returns and riskiness of cropping systems in a thin black chernozem of the Canadian prairies. Soil and Tillage Research 67:9-21.