Zero-tillage management: A response to high fuel prices - Managing risk, residue management and fertilizer management

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Summary

Reducing risk costs in cropping systems is not only about reducing fuel used in tillage, but also about fertilizer costs. The major energy cost in annual cropping is nitrogen fertilizer. The overall energy reduction due to zero-tillage was 2% at Indian Head, with 14% of total energy inputs in fuel and lubricants under zero tillage compared to 20% of total energy inputs under conventional tillage. In drier areas, zero tillage has a more positive energy balance due to higher soil moisture and reduced evaporation. These factors allow more continuous cropping and often higher yields. Under better moisture conditions, such as those in the majority of the black soil zone, the need for moisture conservation is often not as large. In some situations, there may be excess moisture in the spring, which can delay planting and thus has the potential to reduce yields of cool season crops. Warm season crops such as soybean and dry bean often have lower yields under zero tillage in the Red River Valley unless the straw is removed. If the straw is removed, soil temperature may be greater than under conventional tillage. Taller standing stubble reduces wind speed and increases air temperature during the seeding stages, which increased seed yields in Swift Current, but did not increase yield in Brandon. While there is currently no data to support the idea, a good system for planting soybean and dry bean may be tall stubble with surface residue removed. This system would probably be good due to the higher soil and air temperatures it would provide early in the season. However, this may not be suitable for all crops. The extra soil moisture resulting from reduced evaporation from the soil surface could delay planting. Tillage system also influences weed populations due to the physical factors affecting microsites, as well as temperature and moisture. For example, dandelions can become a significant problem under zero tillage if they are not controlled on a regular basis. To limit the establishment of adult plants, dandelions need to be sprayed in the fall or spring with appropriate herbicides. In general, plant diseases have not been significantly affected by tillage system and they have minimal impact on risk. This includes fusarium in cereal grains which has increased in the Red River Valley, where zero tillage is very limited. Under zero tillage, successful establishment of small seeded crops, such as canola, requires that the crop not be planted too deep. Row cleaners or some similar system may be required when crop residues are heavy since residue acts very much like soil in reducing crop establishment. Thus, zero tillage can enhance crop production in some situations. While it does reduce risk of water deficit, it can increase risk due to cool, wet soils, unless alternative management is conducted.

Whole farm risk is a very large and complex issue; thus, for purposes of this paper, I will focus on farming systems which do not include livestock. The discussion will be primarily devoted to how production related risks are impacted by direct seeding. Direct seeding, including zero-tillage (which I define as low disturbance, single pass seeding), is currently a well established management system. Direct seeding employs well designed and constructed seeding equipment and there is a significant body of research information on the impacts of this technology on: 1)moisture 2)temperature 3)wind speed 4)diseases 5)weeds 6)energy and 7)soil quality/nutrients.

Direct seeding has been an important tool to reduce wind and soil erosion. This is due to the direct impact of reducing the amount of erodible soil in all fields where this type of management is used and in drier areas. Direct seeding also increases the amount of stored soil moisture, enabling fallow to be reduced without an excessive increase in risk. In areas where soil moisture can be excessive, direct seeding can delay planting by slowing drying of the soil surface. According to Manitoba Crop insurance data, delayed seeding generally results in lower yields (Fig 1). There is some evidence that delayed seeding impacts are more significant at sites or years when temperatures are warmer. This is consistent with the fact that cool season crops such as wheat have optimal growing temperatures around 18 ^{o}C and when seeding is delayed, some growth happens when temperatures are above optimum for these crops. In addition, delayed planting reduces the number of long days during the growing period, moves crop filling later in the season when rainfall is generally less and increases risk of frost and poor drying conditions later in the season. While delayed seeding is occasionally positive due to drought or late spring frosts, generally planting cool season crops early is a good strategy. Single pass direct seeding allows early planting to happen more easily. Producers who do not practice direct seeding often conduct most of their seedbed preparation operations in the fall so that they can seed as early as possible in the spring, without a large number of pre-seeding tillage operations. Delaying seeding to “grow out” weeds is generally not successful in Manitoba, and it tends to reduce crop yields. An initial flush of weeds such as wild oats are controlled, but in-season precipitation results in multiple flushes of wild oats which limit the effectiveness of this management technique.

Direct seeding can result in cooler soil temperatures and extra moisture, which often means that crops can be planted at a shallower depth. The net result may mean little change in the time of crop emergence. Early work in Manitoba showed that removing straw can increase soil temperatures in direct seeding situations so that these soils were warmer than conventionally tilled soils. At Morden, McAdrew (unpublished) examined treatments including straw removal and burning compared to conventional tillage and direct seeding without straw removal to determine how to enhance direct seeding of soybean and dry bean (Table 1). The yield of these heat-loving crops was lower when they were planted using direct seeding systems, but straw removal or spring tillage alleviated this. In this situation, it appears the conventional tillage or burning may be more cost effective, even with tillage costs included. Since crops like dry bean and soybean generally have less residue, it may be feasible to direct seed cereal grains into these stubbles, while using conventional tillage for soybean and dry bean. This may require extra machinery or custom work, and a complete economic analysis of these operations should be conducted to ensure a positive economic outcome.

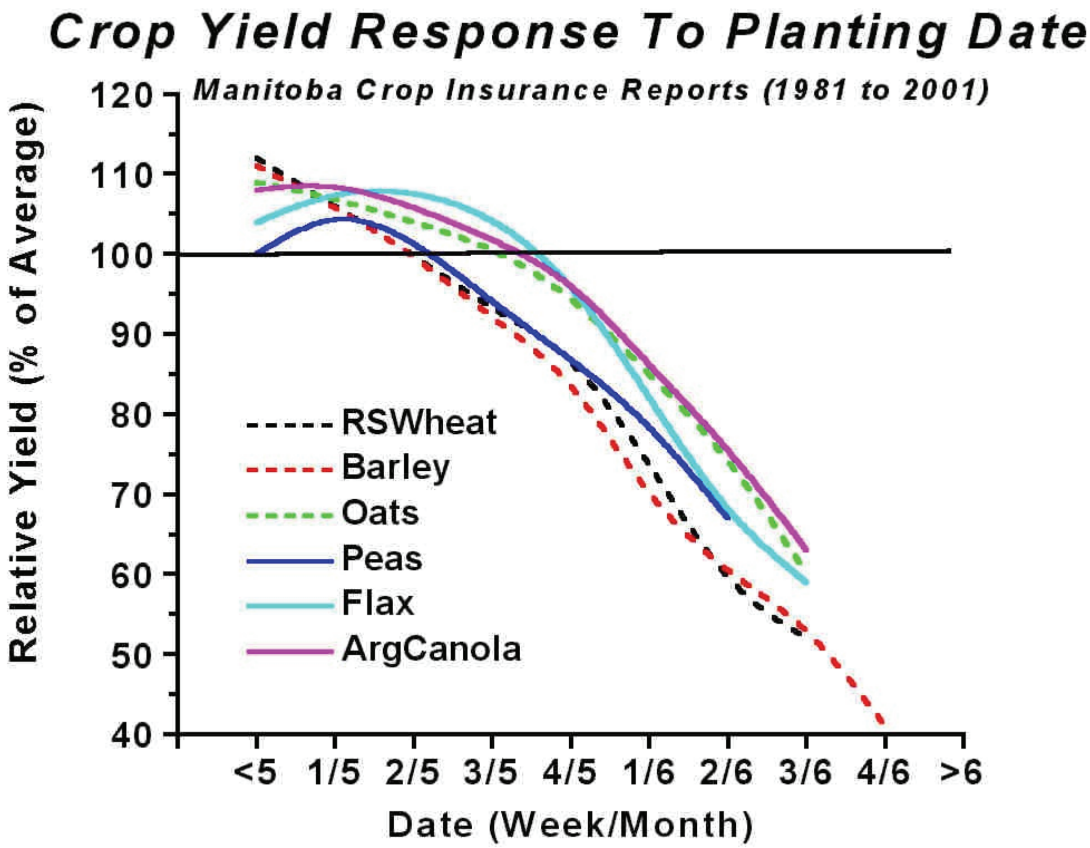

Fig 1. Impact of seeding date on relative yields of crops in Manitoba source[z] Wilcox 2003

Table 1 Impact of Tillage System on warm season crop yields kgha^{-1}

Tillage treatment	Dry Bean	Soy Bean
Zt	2107 (95)	2591(92)
ZT fall burn	2241(101)	2854(101)
Spring Tillage	2307(104)	2950(105)
Fall & Spring tillage	2218(100)	2812(100)

Standing stubble reduces wind speed near the soil surface, reducing the rate of soil drying when the crop canopy is small. At Swift Current, planting into tall stubble has increased seed yields but this was rarely the case in Brandon (Table 2). Since the cost effective technology is available to direct seed between crop rows, it is now possible to direct seed into taller stubble without serious plugging. Given the fact that combine work rate is increased when cutting height is increased and that yields are equal, there is a potential value to direct seeding into tall stubble to take advantage of extra moisture in years when there is a moisture deficit. However, this is unlikely to be wise if the field in question is subject to excess moisture.

Stripper header technology has the potential to increase combine capacity by 50-100% and thereby reduce the energy costs of operation (Tado et al. 1998). The stubble of cereal grains remains very long and, with appropriate seeding equipment, can trap more snow and reduce evaporation. In the relatively moist areas of the Northern Great Plains, greater snow trap may delay planting to such a degree that it would make annual cropping impossible. When straw production is high, it is necessary to add some additional straw cutting tool or other management tool to ensure that seeding can occur without excessive hairpinning (with disc openers) or plugging (when hoe openers are used).

Table 2 Impact of stubble height on crop yields at sites differencing in potential evapotranspiration

	Brandon			Swift Current		
	Canola[z1]	Pea[z1]	Wheat[z1]	Canola[z2]	Pulse[z3]	Wheat[z4]
cult	1560	2667	2471	1239	1782	2225
short	1628	2707	2553	1354	1858	2418
tall	1578	2805	2460	1445	2008	2560
Tukey (.10)	ns	ns	ns	136	161	94

[Z1] Source Volkmar et al report to WGRF [z2] Cutforth et al 2006
[z3]Cutforth et al 2002 [z4]Cutforth and McConkey 1997

In field surveys of Manitoba, Gilbert and Woods (2001) were unable to identify consistent impacts of tillage system on disease levels and where statistically significant differences in disease levels were identified. the differences were of limited biological importance (Table 3).

Table 3 Effect of tillage system in Fields on foliar disease levels

	South Eastern Manitoba		South Western Manitoba	
Pathogen	Conventional	Conservation	Conventional	Conservation
S. nordum blotch	8.6	5.1*	8.8	10.4
S. triticti blotch	35.7	39.1	34.0	16.3**
Spot blotch	20.1	18.6	9.7	6.7
Tan spot	7.1	6.9	9.9	18.1

Gilbert and Woods Can.J. Plant Sci 81:551-559

While it seems intuitive that the energy costs, and thus total costs, would be greatly reduced, this is not often the case since the major energy costs in annual cropping systems are those associated with nitrogen fertilization. In a study at Indian Head, Saskatchewan, energy costs associated with conventional tillage were about 2% higher than those for zero tillage (Table 4). This cost increases in direct portion to the number of tillage operations. While this cost may be relatively small, the impact on net returns can be significant. For example, if the net return to a wheat or canola crop is $25/ac, two extra cultivations may reduce this number by $6-10/ac, which is extremely important.

Zero tillage has a variable impact on weeds, with factors such as crop rotation and in crop weed management having larger impacts than tillage in many situations. Certain weeds, such as green foxtail, are reduced by low disturbance direct seeding. However, the effect of seeding system on wild oats is not as clear and the effect tends to be species specific. Thus, risk may change but the other impact still depends on management in both conventional and direct seeding systems.

Table 4. Impact of crop sequence and tillage method on non-renewable energy inputs, energy output MJ ha^{-1a} and energy use efficiency of spring wheat and pea production at Indian Head (1987-1998)

Energy Source	Spring wheat on cereal stubble		Spring wheat on pea stubble		Pea on cereal stubble	
	CT[b]	ZT[c]	CT	ZT	CT	ZT
Fertilizer	5886	6003	5410	5471	1503	1724
Herbicides	555	779	416	601	411	578
Fuel and lubricants	1688	1132	1693	1140	2329	1674
Machinery overhead	375	340	389	345	502	464
Total energy input	8484 a	8254 b	7908 a	7625 c	4745 a	4440 c
Gross energy output	35713 b	38211 a	42693 ab	40568 b	39038 a	42350 a
Net energy produced	27229 b	29957 a	34785 ab	32943 b	34293 b	37910 a
Grain/energy input[d]	284 b	300 a	354 b	341 b	485 a	594 a
Output/input ratio	4.21 b	4.60 a	5.40 a	5.32 a	8.23 c	9.54a
[Z] adapted from Zenter et al 2004						

[a] Means followed by the same letter do not differ with crop do not differ @ P<0.10
[b] conventional tillage one tillage in fall and one in the spring prior to planting
[c] zero tillage using a hoe opener commercial drill.
[d] Units are kg of grain produced per GJ of energy input.

High disturbance single pass seeding using sweeps is declining, but a single pass system does reduce time. A single pass system also can be a method of reducing fertilizer injury by increasing seed bed utilization. This type of seeding system requires more fuel, but if appropriate control of perennials and winter annuals is conducted in the previous system, this system can be an effective seeding system. Canola must be planted shallow, and it has been found that deeper planting is more damaging with sweeps than when a sidebanding planter is used. The use of sweeps has generally resulted in reduced establishment and thus can add cost when hybrid canola seed is used.

While the overall impact of tillage system on nutrient management is variable, it is obvious that if you are storing carbon, nitrogen is also stored. This nitrogen must come from extra nitrogen fertilizer, reduced nitrogen loss or nitrogen fixation. Nitrogen fixation can be enhanced under zero tillage in some conditions, but under Western Canadian conditions there is currently no evidence for significant amounts of nitrogen fixation by free living organisms. However, if nitrogen accumulates in a rapidly cycling and readily available organic pool, it should be possible to reduce the risk of under-fertilization because, under excellent growing conditions, nitrogen would be released to meet crop needs. There have been numerous reports on the safe distance for fertilizer bands to protect the seed from damage, and there are products on the market to reduce fertilizer damage when fertilizer is placed within the seed row. This subject has been dealt with in many presentations, but it should be noted that care should be taken to limit fertilizer damage in direct seeding systems or risk will be increased rather than decreased. This is very important when using urea based fertilizer on canola planted on soils with low CEC and/or high pH and/or dry soils.

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