Why I Haven't Switched to Direct Seeding

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One of the most important changes I've witnessed in my 35 years of farming is the steady reduction in tillage—both its amount and intensity. When my father began teaching me to farm in 1975, he was moldboard plowing every acre. I now spray glyphosate to kill my grassy weeds and use a rotary chopper to manage my stubble. Tillage is used only to conserve seedbed moisture. In many crop-years, I work my fields only twice—once with a chisel plow and once with a cultivator.[1] I believe my seedbed moisture would be almost as good if I switched to an "undercutter" and tilled only once.

Although I've greatly reduced my tillage, I haven't followed the lead of some of my neighbors who are direct seeding. "Direct seeding" (also called "no-till") means seeding crops directly into the residue from the previous crop without any tillage.[2] In this article, I will explain why I believe some tillage is still important for good crop yields in the dry parts of Eastern Oregon where I farm.

Dry summers and wet winters

The equipment and much of the philosophy behind direct seeding was developed in the Mid-West. The rainfall in the parts of North America located east of the Rocky Mountains occurs primarily in the summer, when storms link up with moisture from the Gulf of Mexico. This summer rainfall pattern allows farmers in the Mid-West to grow corn, soybeans and other warm-season grasses.

The rainfall pattern west of the Rocky Mountains is quite different. Most of the rainfall occurs during winter months. Lack of reliable summer and early fall rainfall means that most of the crop rotations used in the Mid-West are not feasible in the Pacific Northwest (PNW). Dry periods lasting for several months (or longer) are common in the PNW in the summer and fall. Winter wheat that emerges in the early fall is one of the few crops able to develop the deep root system necessary to survive these extended dry periods.

Extended dry periods in the summer and fall also mean that lack of seed-bed moisture can be a serious problem in establishing fall seeded crops. Most of the unique farming methods and farming equipment developed in the PNW over the last 100 years have been aimed at conserving seed-bed moisture and then being able to place wheat seeds deep enough to reach that moist soil—so crops will emerge in the early fall even after extended dry periods.[3]

Effect of tillage on seed-zone moisture

Tillage significantly reduces the evaporation of moisture from the top foot of the soil profile. If properly done, tillage will establish a "moisture line" about four inches below the soil surface. Wheat planted into this moist soil will usually emerge even after a long period without rain. Without tillage, the hot summer sun bakes the moisture out of the top foot, often leaving insufficient moisture available to germinate direct seeded wheat seeds. As will be discussed more below, delayed emergence reduces plant development in the fall and reduces wheat yields—by as much as 30%.

I believe only one valid reason remains for not adopting direct seeding—the yield loss caused by the delayed emergence of direct seeded wheat in many years.[4]

Places in the PNW where direct seeding is likely to work well

All parts of the Pacific Northwest receive most of their rainfall in the period from November through April. However, the higher rainfall areas (those averaging more than 16 inches per year) generally receive enough summer and early fall rainfall so that dry seed beds are not a problem in most years. The adoption of direct seeding should be greater in higher rainfall areas.[5]

Direct seeding is also more likely to be adopted in areas with very steep hills. In order to plant seed into moisture that is 4 or 5 inches below the soil surface, considerable effort has gone into developing and perfecting "deep furrow" drills. These drills have a shank opener to place the seed into the moisture and a large "press wheel" behind the shank opener to make a furrow. The press wheel creates ridges of soil on both sides of the seed and reduces the amount of soil directly over the seed. Less soil over the seed reduces emergence time and increases the ability of the seed to push through surface crusting caused by rain showers. Deep furrow drills work well on flat land or when pulled up or down hills. They do not work well when pulled across a steep slope because the press wheels slide down the hill and cause more soil to be piled over the seeds instead of less. If the moisture is 4 or 5 inches deep, the 2 or 3 inches of added soil-cover from a sliding press wheel make good emergence unlikely. Deep furrow drills have never been used in areas of the PNW where fields are too steep to be farmed up and down the hills. In areas with very steep hills, the benefits of tillage in conserving seed-zone moisture are less important and the main disadvantage of direct seeding is greatly reduced.[6, 7]

Estimating the yield loss under direct seeding

In many of the dry parts of the PNW where deep furrow drills are used, switching to direct seeding will cause a decline in average wheat yields. Yields will be reduced in years when significant fall rains do not arrive until October or November and the emergence of direct seeded wheat is delayed by lack of seed-bed moisture.[8] In years when fall rains start early, yields of direct seeded and deep furrow seeded fields should be similar. The best way to determine the size of the average yield loss would be to conduct a long-term study comparing the yields of direct seeded fields with the yields of adjacent fields with tilled seed beds. Unfortunately, for the low rainfall areas (those averaging less than 12 inches), there are no long-term studies and little side-by-side data. The yield data from the long-term plots at the Sherman Experiment Station show an average 12% yield reduction (60.2 bushels per acre for conventional fallow compared with 52.7 bushels per acre for direct seeded chemical fallow).[9] However, yield data from these plots has been available for only three years—not long enough to average out the big yearly differences in fall rainfall.

Another way to estimate the effect of direct seeding on yields is 1) to use long-term precipitation records to estimate the percentage of crop-years that wheat emergence is likely to be delayed under direct seeding and then 2) combine these estimates with the results of experiments measuring the effects of planting delays on yield.

Estimating the percentage of years when emergence of direct seeded wheat is delayed

I examined precipitation records from the Sherman Experiment Station over the last 30 years and divided the 30 years into three groups:[10]

1. **Normal years**—when at least .51 inches of rainfall occurred in either August or September or both. I assumed that the emergence and yield of direct seeded and tilled fallow fields would be similar during these "normal years."

2. **Dry years**—when less than .51 inches of rainfall occurred in both August and September, but more than .5 inches of rainfall occurred in October. I assumed that in dry years the emergence of direct seeded wheat would be delayed until late October.

3. **Very dry years**—when less than .51 inches of rainfall occurred in August, September, and October. I assumed that in very dry years the emergence of direct seeded wheat would be delayed until late November.

In the 30-year period between 1979 and 2008, there were 15 normal years, 10 dry years (1980, 1989, 1991, 1994, 1999, 2000, 2003, 2005, 2006, and 2007), and five very dry years (1987, 1993, 1998, 2002, and 2008).

Estimating the yield reduction from delayed emergence

Three studies have examined how delayed planting affects yields in the dry areas of the PNW. The yield results from these studies are summarized in the Appendix. The first and most recent study is Dr. Mike Flowers' experiments conducted over the last three years at the Sherman

Experiment Station (see Flowers, et. al. (2008). Dr. Flowers planted six wheat varieties at several different dates in the fall of 2005, 2006, and 2007. I focused on the most common seeding dates from Dr. Flowers' trials. I assumed that the optimum seeding date was October 3rd and that during "dry years" and "very dry years" the emergence of direct seeded wheat would be delayed until October 27th and November 20th, respectively. The planting dates for 2007 don't match the planting dates in the first two years of Dr. Flowers' study, so I could not simply average the data across years. Hence, I ignored data from the early September seeding date and used regression analysis to combine the remaining data and obtain estimates of the average yield reduction caused by delayed emergence.[11]

Predicted Yield Reductions using Dr. Flowers' Data

Planting date	Predicted yield (bushels/acre)	Percent reduction from October 3rd
October 3rd	73.1	0%
October 27th	59.8	18.2%
November 20th	46.5	36.4%

Hence, the estimate of the yield reduction from direct seeding

= [(15 years x 0%)+(10 years x 18.2%)+(5 years x36.4%)]/30
=12.1%

The second study is Russelle and Bolton (1979). I used a similar method to summarize the data. I ignored the dates before September 30th and used regression analysis to combine the two years of data and obtain estimates of the average yield reduction caused by delayed emergence.[12]

Predicted Yield Reductions using Russelle and Bolton's Data

Planting date	Predicted yield (bushels/acre)	Percent reduction from October 3rd
October 3rd	55.7	0%
October 27th	39.0	29.9%
November 20th	22.4	59.7%

Hence, the estimate of the yield reduction from direct seeding

= [(15 years x 0%)+(10 years x 29.9%)+(5 years x 59.7%)]/30
=19.9%

The last study is Donaldson, Schillinger, and Dofing (2001). The annual rainfall at the Lind Experiment Station averages about an inch and a half less than at the Sherman Station and seeding in the surrounding area normally starts about a month earlier. Hence, I moved the yield data from the Donaldson, Schillinger, and Dofing study back a month to better match the other two studies.

Predicted Yield Reductions using Donaldson, Schillinger, and Dofing's Data

Planting date (moved back a month)	Average yield (bushels/acre)	Percent reduction from Late-Sept.
Late-September	61.2	0%
Mid-October	56.3	8.0%
Mid-November	43.7	28.6%

Hence, the estimate of the yield reduction from direct seeding

= [(15 years x 0%)+(10 years x 8.0%)+(5 years x 28.6%)]/30
= 7.4%

When the yield reductions from the three studies are averaged, the result is

(12.1% + 19.9% + 7.4%)/3 = 13.1%

In addition to reducing average yield, switching to direct seeding will increase yield variability and the number of years with much below average yields.

While these estimates need additional refinement, they give an indication of the size of the effect and the kind of additional information needed to calculate the yield reduction from direct seeding more precisely.

The yield reduction estimated above would mean that switching to direct seeding reduces a farm's average gross revenue by approximately

13.1% x 50 bushels per acre x $5 per bushel = $32 per acre.

References:

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(The paper presents yield data in graphical form only. Bill Schillinger provided me with the numerical results.)

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Appendix

Average Wheat Yields at Different Seeding Dates				
1. Flowers. Peterson, Petrie,Machado, Rhinhart, and Chatelain (2008)				
	Sherman Experiment Station			
Planting date		Average Yield (bushel/acre)		
		2006	**2007**	**2008**
12-Sep		68.9	87.6	59.4
3-Oct		74.8	91.3	
10-Oct				53.4
27-Oct		47.8	68.6	
14-Nov				48.2
20-Nov			61.2	
13-Feb				25.1
2. Russelle and Bolton (1979)				
	Sherman Experiment Station			
Planting date		Average Yield (bushel/acre)		
		1976	**1977**	
20-Aug		12.9		
1-Sep			32.4	
4-Sep		27.7		
16-Sep		45.7	48.8	
30-Sep			60.2	
2-Oct		52.2		
12-Oct			55.5	
17-Oct		41.5		
27-Oct			51.6	
30-Oct		26.5		
12-Nov		19.0		
3. Donaldson, Schillinger, and Dofing (2001)				
	Lind Experiment Station			
Planting date		Average Yield (bushel/acre)		
		for **1995**, **1996**, and **1997**		
late-August			61.2	
mid-September			56.3	
mid-October			43.7	

Endnotes:

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[1] When late season rains cause broad leaf weeds to germinate in my fields, I also use a rodweeder once or twice during the summer or early fall. Hence, during some years, I may use as many as four tillage operations.
[2] Like most other parts of Eastern Oregon, the area where I farm has an average annual rainfall of less than 12 inches per year—with rainfall in some years less than 6 inches. To grow a good wheat crop we must use summerfallow—planting a crop every other year on each field and hence storing up two years of moisture. Direct seeded wheat is planted on chemical summerfallow.
[3] For an interesting history of wheat farming in the PNW, see Schillinger and Papendick (2008).
[4] Several studies have shown that the yield of direct seeded wheat is less than the yield of wheat seeded on traditional fallow even when the wheat emerges at the same time under both systems. For example, see Petrie, Albrecht and Long (2006) and Schillinger, Wellsandt, Schafer, Schofstoll and Papendick (2005). Explanations include increased availability of nitrogen when the soil is tilled and better seed bed moisture. Both these papers report a yield reduction of approximately 5%. Given the conservation benefits of direct seeding, I believe farmers can live with a yield reduction of 5%. The much larger and more variable reduction in yields due to lack of seed bed moisture in the fall is the main explanation of why farmers are reluctant to switch to direct seeding in the dry areas.
[5] Besides having better seed-bed moisture in most years, the higher rainfall areas also seem to experience less yield reduction when wheat emergence is delayed.
[6] I'm often asked why Wasco County has adopted direct seeding to a much greater extent than the county where I farm, Sherman County—when the two counties border each other. I believe the explanation involves the very steep slopes in the northern part of Wasco County. Farmers in Wasco County have never been able to seed these steep slopes with deep furrow drills and used disk drills to "dust in" their wheat before they started direct seeding. Switching to direct seeding did not significantly delay emergence in Wasco County. Wasco County also receives about an inch more annual rainfall than Sherman County.
[7] Lutcher and Broderick (2001) discuss a 1976 study by Hammel and Papendick conducted in the Horse Heaven Hills. The study indicates that "the moisture content in the first foot of chemical fallow plots and tillage fallow plots was the same" for a "fine sandy loam soil." This result may explain why direct seeding seems to be more widely used in the areas of my county with sandy soils. Moisture loss in the top foot of chemical fallow may be less in areas with sandy soils.
[8] In this article, I am assuming that seed-bed moisture is sufficient in tilled fallow to germinate wheat at the optimum seeded date. In a small percentage of years, this is not true and tilled seed beds are too dry to germinate wheat in the late September/early October optimum seeding window. In this case, yields of both traditional and direct seeded wheat will be reduced. More study is needed to explain why traditional fallow is sometimes too dry to seed and how often this condition occurs. I had good seed bed moisture in my traditional fallow during the very dry fall of 2008.
[9] See Machado, et. al. (2008).
[10] Monthly precipitation data were taken from various issues of the CBARC annual report. See Agricultural Experiment Station Oregon State University, (2008) **2008 Dryland Agricultural Research Annual Report**, Special Report 1083, page 114. Petrie and Rhinhart (2006) use daily rainfall records from the Pendleton Experiment Station to estimate the probabilities that sufficient rainfall will accumulate by different dates in the fall to cause successful emergence of wheat. The use of daily rainfall data rather than the monthly data used for this study should allow a more precise estimation of when direct seeded wheat will emerge. Steve Petrie has informed me that the daily rainfall records for the Sherman Experiment Station were recently entered into an electronic data base.
[11] The regression equation was

$$\text{Yield} = \text{constant} + a_1(\text{seeding date measured as number of day after October } 3^{rd}) + a_2(\text{dummy variable for 2007}) + a_3(\text{dummy variable for 2008})$$

The results are

Yield = 67.95 – 0.55415(seeding date measured as number of day after October 3rd)
(6.75) (.197)
+ 19.05(dummy variable for 2007) – 3.573(dummy variable for 2008)
(8.50) (9.27)

R^2 = .84 and the numbers in parentheses are standard errors of the coefficients.

[12] The regression equation was

Yield = constant + a_1(seeding date measured as number of day after September 30th)
+ a_2(dummy variable for 1976)

The results are

Yield = 64.76 - .69(seeding date measured as number of day after September 30th)
(3.09) (.12)
- 14.03(dummy variable for1976)
(3.69)

R^2 = .94 and the numbers in parentheses are standard errors of the coefficients.