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Diesel and glyphosate price changes benefit the economics of conservation tillage versus traditional tillage

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Abstract

Recent increases in diesel price and decreases in glyphosate [*N*-(phosphonomethyl) glycine] price should favor the profitability and farmer acceptance of herbicide-intensive conservation tillage systems versus fuel-intensive traditional tillage (TT) systems. Profitability results from a long-term field experiment that compared TT, minimum tillage (MT), and delayed minimum tillage (DMT) systems for winter wheat–(*Triticum aestivum* L.)summer fallow in eastern Washington, USA were calculated using both 1998 and 2005 input prices. Net returns for the MT and DMT systems increased by US$ 6.37 and 6.30 (rotational ha)$^{-1}$, respectively, and net returns to the TT system decreased by US$ 2.36 (rotational ha)$^{-1}$ when 2005 versus 1998 prices were used. Here, rotational ha equals 0.5 ha fallow and 0.5 ha wheat. Focusing on the dominant crop of soft white winter wheat (SWWW), the 2005 price hikes pushed diesel costs up for all systems, from US$ 6.81 (rotational ha)$^{-1}$ for DMT to US$ 9.00 (rotational ha)$^{-1}$ for TT. The cost of diesel for the conservation tillage systems, relative to the cost for TT, decreased by US$ 1.50–2.20 (rotational ha)$^{-1}$. The conservation tillage systems accrue greater savings from the price reduction in glyphosate because they consume more of this herbicide. An unanticipated result was that relative cost savings from price changes in N fertilizer rivaled those from diesel and glyphosate because anhydrous NH_3–N was exclusively used in the experiment for TT and aqueous NH_3–N for MT and DMT. The price of anhydrous NH_3–N increased from US$ 0.55 kg^{-1} in 1998 to 0.85 kg^{-1} in 2005, a 56% increase. Aqueous NH_3–N only increased from $0.75 kg^{-1} in 1998 to 0.85 kg^{-1} in 2005, a 15% increase. The greater price increase for anhydrous NH_3–N penalized the TT system because of its use of this fertilizer. If the same source of N fertilizer were used on all three tillage systems, this fertilizer cost effect would disappear. Nonetheless, the conservation tillage systems still retained a statistically significant profitability advantage over TT even if the same fertilizer was used throughout. The sharp price increase for diesel and the concurrent price decrease for glyphosate herbicide favored the conservation tillage systems over TT in this study. Results provide strong evidence for the superior profitability of conservation tillage winter wheat–summer fallow under current economic conditions.

Keywords: Conservation tillage; Economics; Diesel; Glyphosate; Wind erosion; Winter wheat–summer fallow

1. Introduction

Most research on the economics of conservation tillage in the U.S. has been located in the Great Plains and the Corn Belt (Dhuyvetter et al., 1996; Halvorson et al., 1994; Uri, 1999; Weersink et al., 1992; Wiese et al., 1994; Williams, 1988). Recent research has also

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Abbreviations: DMT, delayed minimum tillage; HRSW, hard red spring wheat; MT, minimum tillage; SWWW, soft white winter wheat; TT, traditional tillage

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examined the economics of conservation tillage in the unique agro-climatic conditions of the Pacific Northwest (Janosky et al., 2002; Nail et al., 2005; Papendick, 1996; Schillinger and Young, 2004; Young et al., 1984, 1999). Regardless of region, economic studies have shown that the profitability and riskiness of conservation tillage varies by sub-region and the particular technology employed. Furthermore, these studies have generally evaluated the relative profitability of conservation tillage for the output and input prices of a particular era. Just as new technology such as suitable crop cultivars, improved drills, and new herbicides can improve the economics of conservation tillage cropping systems, major price shifts in important inputs such as glyphosate herbicide and diesel can alter profitability rankings of traditional and conservation tillage practices. The past decade has witnessed major changes in opposite directions of prices of fuel and glyphosate herbicide whose use is decreased and increased, respectively, by adopting conservation tillage. The cost of gasoline and diesel has increased sharply since 1998 (Fig. 1). From April 1998 to April 2005, the nominal price per liter for diesel in the United States, adjusted for farmers' road and excise tax exemptions, rose from US$ 0.20 to 0.52, or 160% (National Agricultural Statistical Service, 2005). Measured in real (constant purchasing power year 2000 dollars) prices, diesel rose 175% between 1998 and 2004 (Bureau of Economic Analysis, 2005). As farmers and motorists know, fuel prices continued to increase in 2005, peaking after the supply disruption caused by Hurricanes Katrina and Rita in late summer. In spring 2006, fuel prices initially fell then rose again. While fuel costs are likely to continue to fluctuate, sustained high petroleum demand from China, India, and the United States are predicted to keep future fuel prices well above historic levels (*The Economist*, "The Oiloholics," 27 Aug. 2005). Concurrently, the price of glyphosate herbicide has decreased over the past several years (Fig. 2), mostly due to expiration of patent protection (National Agricultural Statistical Service, 2005). From April 1998 to April 2005, the nominal price per liter for glyphosate dropped 38% from US$ 14.29 to 8.93. The real price of glyphosate dropped 25% between 1998 and 2004 (date of most recent data) (Bureau of Economic Analysis, 2005).

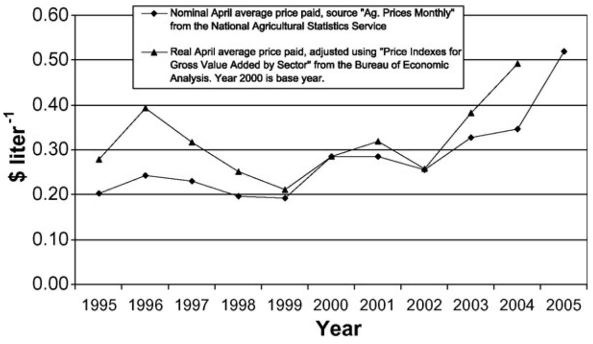

Fig. 1. Average price for bulk delivery diesel fuel, state road and federal excise tax excluded, United States 1995–2005.

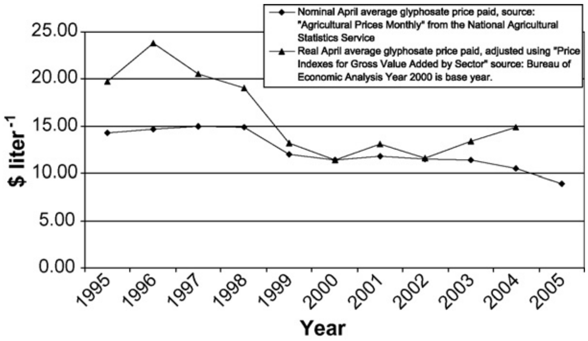

Fig. 2. Average retail glyphosate prices paid by U.S. farmers from 1995 to 2005.

The objective of this study was to compute the effect of using 1998 (Janosky et al., 2002) versus 2005 input prices on the economics of a long-term experiment that compared three tillage management systems in a winter wheat–summer fallow rotation. Our hypothesis was that recent shifts in diesel and glyphosate prices would strengthen the economic competitiveness of conservation tillage relative to traditional tillage.

2. Materials and methods

2.1. Overview

A 6-year tillage management study was conducted from August 1993 to July 1999 at the Washington State University Dryland Research Station at Lind, WA. The first fallow year began in 1993, but economic results are based on the 5 grain harvest years from 1995 to 1999. Average (85-year) annual precipitation is 242 mm. Soil is a Shano silt loam (coarse-silty, mixed, superactive mesic, Xeric Haplocambids) (U.S. classification system). The soil is more than 2 m deep with no rocks or restrictive layers and slope is less than 2%. The experimental design was a randomized complete block with three tillage treatments replicated four times. Wheat and fallow phases of the experiment were present each year.

The three tillage treatments were (i) traditional tillage (TT)—standard frequency and timing of tillage operations using implements commonly utilized by

Table 1
Annual wheat grain yield (Mg ha^{-1}) by three fallow tillage systems (adapted from Schillinger, 2001)

Fallow tillage system	Year					Average[b]
	1995[a]	1996	1997	1998	1999	
Conventional (CT)	1.79	3.52	5.13	3.89	2.32	3.72
Minimum (MT)	1.91	3.76	5.20	3.89	2.69	3.89
Delayed minimum (DMT)	1.79	3.73	4.94	3.58	2.48	3.68
	NS	NS	NS	NS	NS	NS

[a] Fallow tillage systems were initiated in August 1993 and the first winter wheat was sown in September 1994. Due to insufficient seed-zone water the winter wheat stand failed in fall 1994 and hard red spring wheat was sown in March 1995. Within-column means show no significant grain yield differences at $P < 0.05$ in any year or when averaged across years.

[b] Average soft white winter wheat yield (1996–1999).

farmers (ii) minimum tillage (MT)—standard frequency and timing of tillage operations, but herbicides were substituted for tillage when feasible and a non-inversion undercutter V-sweep implement was used for primary spring tillage, and (iii) delayed minimum tillage (DMT)—similar to MT except primary spring tillage with the undercutter V-sweep was delayed until at least mid May. See Schillinger (2001) for a complete description of tillage equipment and field operations used in the experiment.

Table 1 presents annual grain yields for the complete experiment. The 4-year average (1996–1999) soft white winter wheat (SWWW) grain yield from the experiment was 3.72, 3.89, and 3.68 Mg ha^{-1} for TT, MT, and DMT, respectively. The 1995 hard red spring wheat (HRSW) grain yield for the experiment was 1.79, 1.91, 1.79 Mg ha^{-1} for TT, MT, and DMT, respectively. There were no significant differences in wheat grain yield among treatments during any year or when averaged over 5 years (Schillinger, 2001).

2.2. Economic assessment

Winter wheat stand establishment failed due to dry seedbed conditions during the first year of the experiment and all plots were replanted to HRSW. For the purpose of economic analysis, we assume that winter wheat will fail once every 5 years due to either inadequate seed-zone moisture for planting in late summer or winter kill, both of which necessitate replanting to spring wheat.

Economic cost of production budgets were calculated and compared for the three tillage systems in a winter wheat–summer fallow rotation using 1998 and 2005 nominal input prices (Table 2). Nominal prices were used in order to provide a reader-accessible "snapshot" of nominal profitability under the input price regimes of these two periods. Nominal prices have the advantage of being more understandable to non-economists since they are what farmers and others tend to recall. As shown in Figs. 1 and 2, nominal and real (inflation adjusted) prices generally followed the same trend during 1998 and 2005, so the results will be similar in nominal and real terms. Average yields and output prices were held constant over this relatively short period in order to separate the effect of input price changes.

Table 2
Input prices in 1998 and 2005 used in computing the production cost budgets for the long-term tillage systems experiment at Lind, WA

Item	1998 Price (US$)	2005 Price (US$)
Services		
Fire and hail insurance (ha)	5.93	8.69
Rental of 24-m-wide sprayer (ha)	2.84	3.46
In/out storage charge (kg)	0.0029	0
Monthly storage charge (kg)	0.0007	0.0008
Materials		
Gasoline[a] (L)	0.32	0.64
Diesel (L)	0.21	0.55
Soft white winter wheat seed (kg)	0.36	0.29
Hard red spring wheat seed (kg)	0.43	0.37
Aqua NH_3–N (kg)	0.75	0.85
Anhydrous NH_3–N (kg)	0.55	0.85
Surfactant-(NH_4SO_4) (kg)	1.15	0.79
Glyphosate-(Roundup Ultra[b]) (L)	13.51	8.95
Surfactant-general (L)	5.28	3.57
Herbicide—bromoxynil (L)	16.22	13.34
Herbicide—2,4-D ester (L)	4.05	3.72
Other		
Land taxes (ha)	7.41	9.88
Machine operator labor (h)	10	10
Truck driver labor (h)	6.5	8
Combine driver labor (h)	12	14
Interest rate	0.07	0.09

[a] Per National Agricultural Statistical Service (2005), the gasoline price includes government road taxes, but diesel price excludes state road taxes due to predominant farm use.

[b] Roundup Ultra was not available in 2005. The 2005 glyphosate price was based on the price of Roundup RT Master II and adjusted to reflect that Roundup RT Master II has one third more active ingredient than Roundup Ultra.

Economic budgets differ from cash budgets as they include total costs, including opportunity costs. The true cost or opportunity cost of owned inputs is what the farm owner-operator foregoes from not renting out these assets at market rates. Opportunity costs are charged for all owned assets that do not require a cash outlay by the farmer, such as owned land, owner's equity in machinery, and the owner-operator's labor and management. Computing total costs of all resources used in production permits accurate comparison regardless of the asset ownership structure of different farms. New budgets were constructed for 1998 and 2005 input prices, as opposed to merely restating values reported by Janosky et al. (2002). This ensures consistent budgeting methodology and input levels for both eras. Input levels and cultural practices were recollected from the original experiment records to ensure accuracy. The assumption of constant input rates over the two eras requires inelastic (not price sensitive) input demand. While demand for agrichemical inputs typically is inelastic in the short-run, demand exhibits more sensitivity to prices in the long run. Consequently, the effects of price changes reported in this analysis are short-run estimates that could be dampened in the long run.

Variable costs vary with the number of hectares planted. Machinery repairs, fuel, labor, custom hire, seed, fertilizers, herbicides, storage, operating interest, and crop insurance are examples of variable costs. An operating interest charge was also assessed on the variable costs associated with the summer fallow period. Overhead expenses were estimated in both the 1998 and 2005 budgets at 5% of variable costs. Farmers must earn positive returns over variable costs to justify continuing farming in the short run. Otherwise, returns are insufficient to pay for the variable inputs that can be controlled in the short run. Positive returns over total costs are required in the long run, when selling all farm assets is an option.

For a given land and machinery base, fixed costs do not vary with the area planted. The machinery complement used is the same as in Janosky et al. (2002). Machinery fixed costs include depreciation, interest, taxes, housing, and insurance. Depreciation was calculated on a straight-line basis over the life of equipment. Tractor and machinery interest costs were calculated on the average annual machine investment. Following national trends, interest on average investment and operating loans was 9% in 1998 and 7% in 2005.

Land fixed costs include property taxes and net rent. Net rent is either actual land rent paid by the farmer or rental income foregone for land the farmer owns. In eastern Washington, net rent is based on the prevailing 1/3 landlord and 2/3 tenant wheat crop share, with the landlord paying land taxes, and 1/3 of the fertilizer, storage, and crop insurance expenses. Five-year 1993–1997 average market wheat prices of US\$ 144.02 Mg^{-1} for SWWW and US\$187.22 Mg^{-1} for HRSW were retained from Janosky et al. (2002) in order to hold constant all factors except input price changes. These long run average prices are only slightly higher than more recent 5-year average prices (Nail et al., 2005; Schillinger and Young, 2004). All cost and revenue figures are presented on a rotational-hectare basis, i.e., 0.5 ha wheat and 0.5 ha fallow. This correctly portrays the average return per hectare per year of a farmer who has one-half of the farm in winter wheat and one-half in summer fallow.

3. Results and discussion

Table 2 lists 1998 input prices from Janosky et al. (2002) compared to those in April 2005. The price of most inputs, not only fuel and glyphosate, changed over

Table 3
Average input rates of three tillage systems for production of soft white winter wheat (SWWW) and hard red spring wheat (HRSW) for the long-term tillage systems experiment at Lind, Washington

Input	Tillage system					
	Traditional		Minimum		Delayed minimum	
	SWWW	HRSW	SWWW	HRSW	SWWW	HRSW
Diesel, L (rotational ha)$^{-1}$	26.48	29.29	22.08	26.86	20.03	25.73
Glyphosate, L (rotational ha)$^{-1}$	0.58	0.58	1.20	1.28	1.20	1.28
Anhydrous NH_3–N, kg (rotational ha)$^{-1}$	22.42	22.42	0	0	0	0
Aqueous NH_3–N, kg (rotational ha)$^{-1}$	0	0	22.42	22.42	22.42	22.42
Surfactant (NH_4SO_4), kg (rotational ha)$^{-1}$	0.95	0.95	1.33	1.91	1.33	1.91
Herbicide—2,4-D ester[a], L (rotational ha)$^{-1}$	0	0	0	0.80	0	0.80
Machine labor, h (rotational ha)$^{-1}$	2.28	2.59	1.98	2.32	1.83	2.23
Truck driver labor, h (rotational ha)$^{-1}$	0.58	0.62	0.58	0.62	0.58	0.62
Combine driver labor, h (rotational ha)$^{-1}$	0.26	0.26	0.26	0.26	0.26	0.26

[a] 2,4-D was only used only in 1993, the fallow year preceding the replant and harvest of HRSW, as part of the Roundup RT Master II herbicide formulation (Schillinger, 2001).

Table 4
Average costs per rotational hectare calculated using and 2005 input prices, US$ (rotational ha)$^{-1}$ by treatment for the long term (1993–1999) tillage system experiment at Lind, WA[a]

Tillage system	Variable cost		Total cost	
	1998	2005	1998	2005
Traditional tillage	146.83	155.78	284.09	286.45
Minimum tillage	155.70	153.81	284.74	278.37
Delayed minimum tillage	152.27	149.40	273.44	267.14

[a] Weighted average of 80% soft white winter wheat and 20% hard red spring wheat.

the 7-year period. For example, the cost of anhydrous NH_3–N rose by 55% from US$ 0.55 to 0.85 kg^{-1} (Table 2). Table 3 shows the average experiment application rates of selected inputs by tillage system and crop (Janosky et al., 2002; Schillinger, 2001). The data reveal that TT consumes more diesel fuel and labor. The MT and DMT systems use more glyphosate. For example, TT SWWW-fallow uses 32% more diesel than the DMT system (26 L versus 20 L (rotational ha)$^{-1}$). The same comparison shows 106% more glyphosate used for DMT relative to TT.

Tables 3 and 4 report tillage system costs and net returns for both 1998 and 2005 nominal input prices. Table 4 lists the average variable and total cost per rotational hectare of each tillage system using both price levels. The costs are weighted averages of those for SWWW at 80% and for HRSW at 20%. This weighting represents the fact that SWWW is replanted to HRSW in 1 of 5 years. Table 5 presents a comparison of the net returns over variable and over total costs of each tillage system for the two input price levels. The results for 1998 prices in Tables 3 and 4 differ slightly from those in Janosky et al. (2002) due to small differences in budgeting methodology and data. The use of 2005 input prices instead of 1998 prices increases the total cost of TT, and reduces the returns over total costs of TT, by US$ 2.36 (rotational ha)$^{-1}$. The differences over input price levels for total cost and net returns over total cost are identical because revenue based on experiment average grain yields and common crop prices is constant for both input price levels. In contrast to TT, the 2005 input prices boosted profits for both MT and DMT. Total costs decreased and net returns over total costs increased by US$ 6.37 and 6.30 (rotational ha)$^{-1}$ for MT and DMT, respectively (Tables 3 and 4).

The MT and DMT systems averaged significantly higher net returns over total costs under both 1998 and 2005 input prices compared to TT (Table 5). For 2005 prices, MT and DMT systems' net returns over total costs are statistically superior to those for TT at the $P < 0.000001$ probability level. For the 1998 price scenario, the MT and DMT systems' statistical advantage over TT occurs at the $P < 0.01$ probability level. The statistical advantage at 2005 prices of conservation tillage versus TT is preserved for returns over variable costs for MT, but not DMT (Table 5). The statistical advantage for DMT occurs for returns over total costs because machinery fixed costs are relatively higher for TT than DMT and this widens the profitability gap.

These results confirm the hypothesis that recent price shifts for diesel, glyphosate, and possibly other inputs have strengthened the economic competitiveness of conservation tillage for winter wheat–summer fallow farming in the Pacific Northwest. Janosky et al. (2002) showed no statistical difference among tillage systems with 1998 prices due to slightly different net return results and methodology. As previously mentioned, the results for this comparison are strengthened because all methodology and data have been held constant over time periods except for input prices.

Table 5
Net returns, US$ (rotational ha)$^{-1}$ for three tillage systems for winter wheat–summer fallow farming using 1998 and 2005 production costs[a]

Tillage system	Revenue	Net returns over cost using		Net returns over cost using	
		1998 Input prices		2005 Input prices	
		Variable	Total	Variable	Total
Traditional tillage	247.73	100.90ab	−36.36b	91.95b	−38.72b
Minimum tillage	259.67	103.97a	−25.07a	105.86a	−18.70a
Delayed minimum tillage	245.56	93.29b	−27.88a	96.16ab	−21.58a

Average net returns followed by the same letter are not significantly different at $P < 0.05$. The $LSD_{.05}$ for the average net returns over variable costs per rotational hectare of the three tillage systems computed using 1998 input prices is US$ 9.96 and 10.02 ha^{-1} for 2005 prices. The $LSD_{.05}$ for the average net returns over total costs per rotational hectare of the three tillage system computed using 1998 input prices is US$ 6.78 and 6.89 ha^{-1} for 2005 prices. For 2005 prices, net returns over total costs for minimum and delayed minimum tillage systems are statistically superior to traditional tillage at $P < 0.000001$. For 1998 prices, net returns over total costs for minimum and delayed minimum tillage systems are statistically superior to traditional tillage at $P < 0.01$.

[a] Weighted average of 80% soft white winter wheat and 20% hard red spring wheat.

Table 6
Changes in variable, fixed, and total costs, US\$ (rotational ha)$^{-1}$ from 1998 to 2005 for three tillage systems by cost component[a]

Tillage system	Variable	Fixed	Total
Traditional tillage	8.95	−6.59	2.36
Relative to traditional tillage	0	0	0
Minimum tillage	−1.89	−4.48	−6.37
Relative to traditional tillage	−10.84	2.11	−8.73
Delayed minimum tillage	−2.87	−3.43	−6.3
Relative to traditional tillage	−11.82	3.16	−8.66

[a] Weighted average of 80% soft white winter wheat and 20% hard red spring wheat.

Table 6 explains the sources of the conservation tillage systems' increasing economic advantage over TT with the change in input prices. It shows variable costs increased by US\$ 8.95 (rotational ha)$^{-1}$ for TT with 2005 prices, but variable costs of the conservation tillage systems fell by US\$ 1.89 and 2.87 (rotational ha)$^{-1}$. Fixed costs fell for all three tillage systems, primarily due to decreased interest rates, but they fell more for TT because this system had a larger machinery complement and correspondingly higher interest bill. The sum of variable and fixed costs resulted in total costs increasing by US\$ 2.36 (rotational ha)$^{-1}$ for TT, and falling by about US\$ 6 (rotational ha)$^{-1}$, as previously calculated from Table 4, for MT and DMT. Table 7 lists the relative changes in costs for MT and DMT compared to the cost changes for the TT. These comparisons show that the conservation tillage systems experienced variable cost reductions relative to TT of US\$ 10.84 and 11.82 (rotational ha)$^{-1}$, but had corresponding relative increases of US\$ 2.11 and 3.16 (rotational ha)$^{-1}$ for fixed costs. In sum, the relative total cost reductions were US\$ 8.73 and 8.66 (rotational ha)$^{-1}$for MT and DMT, respectively.

Table 7
Change in cost, US\$ (rotational ha)$^{-1}$ from 1998 to 2005 of selected inputs for soft white winter wheat (SWWW) and hard red spring wheat (HRSW) production for three tillage systems at Lind, WA

System/crop	Input		
	Diesel	Nitrogen fertilizer[a]	Glyphosate
Traditional tillage			
SWWW	9.01	6.75	−2.87
HRSW	9.96	6.75	−2.87
Relative to traditional tillage			
SWWW	0	0	0
HRSW	0	0	0
Minimum tillage			
SWWW	7.51	2.25	−5.50
HRSW	9.13	2.25	−5.84
Relative to traditional tillage			
SWWW	−1.50	−4.50	−2.63
HRSW	−0.83	−4.50	−2.97
Delayed minimum tillage			
SWWW	6.81	2.25	−5.50
HRSW	8.75	2.25	−5.84
Relative to traditional tillage			
SWWW	−2.20	−4.50	−2.63
HRSW	−1.21	−4.50	−2.97

[a] The nitrogen fertilizer is anhydrous NH_3–N for traditional tillage and aqua NH_3–N for minimum tillage and delayed minimum tillage.

Table 7 presents the contribution of diesel, N fertilizer, and glyphosate herbicide to the relative variable cost reductions by tillage system and crop. Because several unlisted inputs experienced price changes in both directions (Table 2), Table 7 provides only a partial picture of variable cost changes. Focusing on the dominant crop of SWWW, the 2005 price hikes pushed diesel costs up for all systems, from US\$ 6.81 (rotational ha)$^{-1}$ for DMT to US\$ 9.00 (rotational ha)$^{-1}$ for TT. The cost of diesel for the conservation tillage systems decreased only US\$ 1.50–2.20 (rotational ha)$^{-1}$ relative to TT. The conservation tillage systems accrue greater savings from the price reduction in glyphosate because they consume more of this herbicide (Table 4). An unanticipated result was that relative cost savings from price changes in N fertilizer rivaled those from diesel and glyphosate (Table 7) because anhydrous NH_3–N was exclusively used in the experiment for TT and aqueous NH_3–N for MT and DMT. The greater price increase for anhydrous NH_3–N penalized the TT system because of its use of this fertilizer. If the same source of N fertilizer were used on all three tillage systems, this fertilizer cost effect would disappear. However, narrowing the

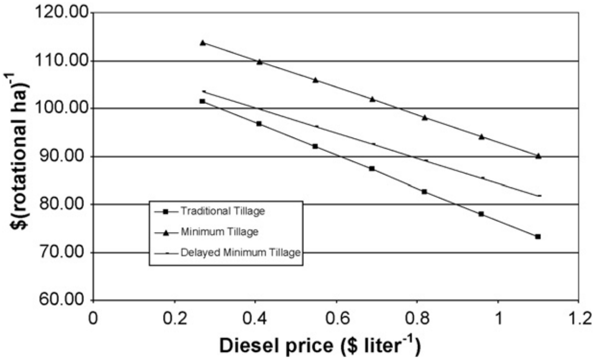

Fig. 3. Net returns over variable costs for three tillage systems with diesel prices ranging from 50 to 200% of the April 2005 price of diesel.

profitability differences in Table 5 by US$ 4.50 (rotational ha)$^{-1}$, the amount of the fertilizer choice effect in Table 7, would still preserve the statistically significant profitability advantage for the conservation tillage systems.

Considerable speculation has recently focused on the effects of future changes in the price of diesel and other petroleum products on agricultural production. The uncertainty surrounding petroleum world supply and demand changes make it difficult to forecast future diesel prices. Consequently, Fig. 3 shows the influence of diesel prices ranging from 50 to 200% of the April 2005 price on returns over variable costs for the three tillage systems in this study. Of course, all three tillage systems show decreasing returns as diesel price increases. At \$0.55 L^{-1} (the 2005 price in Table 2), the curves in Fig. 3 intersect the net returns over variable costs shown in Table 5. The curves display an expected growing net returns advantage between the conservation tillage and TT systems as diesel price increases, albeit all systems are declining in profitability in absolute terms.

4. Summary and conclusions

Using 2005 versus 1998 input prices in the economic analysis of a winter wheat–summer fallow tillage system experiment in eastern Washington strengthened the relative profitability advantage of two conservation tillage systems compared to traditional tillage. Sharp increases in diesel prices penalized the TT system due to more diesel consumption. The conservation tillage systems consumed more glyphosate herbicide, but that cost was cushioned by a decline in glyphosate prices. Use of aqueous NH_3–N instead of anhydrous NH_3–N also favored the conservation tillage systems as aqueous NH_3–N experienced a more moderate price increase between 1998 and 2005. Using the same N fertilizer source for all three tillage systems would have narrowed the profitability advantage for the conservation tillage systems, but they would have still remained significantly more profitable than TT. The updated economic results in this comparison provide strong evidence for the relative profitability of conservation tillage for winter wheat–summer fallow farming in low precipitation regions of eastern Washington.

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