Economics of Alternative No-Till Spring Crop Rotations in Washington's Wheat–Fallow Region

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ABSTRACT

Winter wheat [*Triticum aestivum* L.] (WW)–summer fallow (SF) is the dominant cropping system in the low-precipitation (<300 mm annual) region of the inland Pacific Northwest (PNW), USA. Intensive tillage during SF often leaves soil vulnerable to wind erosion. While no-till cropping is well known for wind erosion control benefits, previous research in the inland PNW showed that annual no-till hard red spring wheat (HRSW) trailed WW–SF in profitability by \$113 ha^{-1} yr^{-1}. Our objective was to assess the agronomic and economic feasibility of alternative no-till spring grain and oilseed rotations in a 5-yr experiment near Ritzville, WA. Spring crops were soft white wheat (SW), barley [*Hordeum vulgare* L.] (SB) yellow mustard [*Brassica hirta* Moench] (YM), and safflower [*Carthamus tinctorius* L.] (SAF) grown in three rotation sequences. Net returns from WW–SF on 10 neighboring farms during the 5-yr period averaged \$21.52 ha^{-1} yr^{-1}. The most profitable no-till spring cropping sequence was continuous SW, which averaged net returns of \$12.11 ha^{-1} yr^{-1}, equivalent to WW–SF and much more competitive than previous HRSW results. No-till SW–SB and a 4-yr rotation of SAF–YM–SW–SW averaged −\$12.10 and −\$31.45 ha^{-1} yr^{-1}, respectively. Although all no-till spring crop rotations had higher annual income variability than WW–SF, positive net returns for continuous SW is the first economic good news for continuous annual cropping using no-till in the low-precipitation region of the inland PNW.

Potential for economic and environmental benefits is a driving force in the gradual shift by dryland farmers to adopt reduced-till and no-till farming methods. Despite several associated environmental problems, WW–SF is the dominant cropping system in the low-precipitation zone of the inland PNW because it provides agronomic and economic advantages (Leggett et al., 1974). Farmers and bankers appreciate time-proven grain yield and income stability of WW–SF and the system's relatively uniform seasonal demands on farm machinery and labor.

Environmental disadvantages of WW–SF include recurrent wind erosion, especially during drought cycles when straw production is low. Summer-fallowed fields in south-central Washington were reported to have lost 4 to 10 cm (240–600 Mg ha^{-1}) of topsoil from wind erosion in one season (Papendick, 1996). In addition to degrading soil, blowing dust from SF also inflicts substantial off-site damage on human respiratory health, traffic accidents, and cleanup costs (Upadhyay et al., 2003). Research in the PNW and elsewhere has shown that no-till cropping controls soil erosion, builds soil quality, and reduces machinery wear and fuel consumption compared with tillage-based systems. More diverse cropping systems than WW–SF also offer opportunities for weed, disease, and insect control (Papendick and Parr, 1996; Withers et al., 1999).

Nationwide, the advantages of annual cropping in semiarid regions have led to substantial adoption. Farmers in the USA reduced SF acreage by 43% from 1964 to 1997, with the largest reductions in the Great Plains (Smith and Young, 2000). In 2000, about 36% of total U.S. cropland was in conservation till or no-till whereas in Washington State, it was only 23% (CTIC, 2001). In east-central Washington and north-central Oregon, where annual precipitation ranges from 150 to 300 mm and WW–SF cropping is practiced on 1.5 million ha, even minimum tillage is rare. In Adams County, WA, where this study is located, conservation tillage is practiced on only 17% of the cropland (CTIC, 2001).

Farmers in the WW–SF region are slow to adopt conservation tillage SF despite conclusive research showing environmental benefits with no agronomic (Schillinger, 2001) or economic (Janosky et al., 2002) disadvantages compared with intensive tillage SF. Concerns about economic risk and profitability appear to be a barrier to adoption of reduced-tillage systems (Juergens et al., 2001).

Few farmers in the PNW low-precipitation region practice continuous annual cropping (CTIC, 2001). Two recent multiyear experiments in Washington compared profitability of no-till HRSW in 150-mm (Benton County) and 290-mm (Adams County) precipitation zones. In Benton County, 1997–2002 net returns over total costs before government farm payments averaged −\$109 ha^{-1} yr^{-1} for annual no-till HRSW and −\$14 ha^{-1} yr^{-1} for WW–SF (Young, 2002a). In Adams County from 1996–2002, the values were −\$122 ha^{-1} yr^{-1} for HRSW compared with \$9 ha^{-1} yr^{-1} for WW–SF (Young, 2002b). The average shortfall of −\$113 ha^{-1} yr^{-1} translates into −\$181 000 yr^{-1} for a typical 1600-ha farm in the region. The WW–SF system was not only more profitable than annual HRSW in both studies, but also demonstrated less annual income risk.

Given the unpromising economic comparison of annual no-till HRSW with WW–SF, a need clearly exists for alternative cropping systems that offer greater economic viability. The objective of this study was to evaluate the economic performance of three annual spring cropping systems involving SW, SB, YM, and SAF and compare them with the WW–SF system practiced on neighboring farms.

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Abbreviations: HRSW, hard red spring wheat; PNW, Pacific Northwest; SAF, safflower; SB, spring barley; SD, standard deviation; SF, summer fallow; SW, soft white spring wheat; WW, winter wheat; YM, yellow mustard.

MATERIALS AND METHODS

Field Layout and Treatments

A 5-yr study of no-till annual spring cropping systems was conducted from 1997 to 2001 at the Ron Jirava farm near Ritzville, Adams County, WA. Cropping systems were (i) a 4-yr SAF–YM–SW–SW rotation, (ii) a 2-yr SW–SB rotation, and (iii) continuous SW. The experiment covered 8 ha, and the soil is a uniform Ritzville silt loam (coarse-silty, mixed, mesic Calcidic Haploxeroll). Soil depth is >2 m, with no restrictive layers, and slopes are <1%. Average annual precipitation at the site is 290 mm. The field where the experiment was established had been planted to spring wheat in 1996 following decades of WW–SF.

Experimental design was a randomized complete block with four replications. Each crop in all rotations occurred each year in 20- by 150-m plots, making a total of 28 plots. During the first 3 yr (1997, 1998, and 1999), all plots were planted and fertilized in one-pass directly into the undisturbed soil and residue left by the previous crop using the grower's Flexi-Coil 6000 air-delivery no-till drill equipped with Barton II dual-disk openers on 19-cm spacing for simultaneous and precision placement of seed and fertilizer in the same row. In 2000 and 2001, all plots were planted and fertilized in one-pass using a custom-built no-till drill equipped with Cross-Slot notched-coulter openers on 20-cm spacing for simultaneous and precision placement of seed and fertilizer in the same row. Both openers are low-disturbance and place fertilizer beneath and slightly to one side of the seed. Glyphosate herbicide [*N*-(phosphonomethyl) glycine] was applied 2 to 4 wk before planting at 0.43 kg acid equivalent (a.e.) ha^{-1} to control weeds and disease green bridge (Smiley et al., 1992). Seeding rate averaged across years was 78, 78, 23, and 10 kg ha^{-1} for SW, SB, SAF, and YM, respectively. Solution 32 (NH_4NO_3 + urea) provided the base for liquid fertilizer to supply an average of 40, 11, and 17 kg ha^{-1} N, P (aqueous solution of $NH_4H_2PO_4$), and S [aqueous solution of $(NH_4)_2S_2O_3$], respectively. The quantity of available soil water and residual N, P, and S was measured in all rotations each spring to determine fertilizer needs based on a yield goal. Between the tillering and jointing phase of growth of SW and SB, in-crop broadleaf weeds were controlled with 0.84 kg a.e. ha^{-1} 2,4-D (2,4-dichlorophenoxyacetic acid) + 0.9×10^{-2} L active ingredient (a.i.) ha^{-1} Harmony Extra (50% thifensulfuron {3-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl) amino]carbonyl]amino]sulfonyl]-2-thiophenecarboxylic acid} + 25% tribenuron {2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl) methylamino]carbonyl]amino]sulfonyl]benzoic acid}). In-crop herbicides were not used in SAF or YM plots as no legally labeled broadleaf weed herbicides were available for these crops in Washington.

All plots were harvested with a commercial-size combine, and grain yield was determined on site by auguring grain into a weigh wagon. When Russian thistle (*Salsola iberica* Sennen and Pau) and other broadleaf weeds were present at time of harvest in cereals (1999 and 2001 only) and broadleaf crops (all years), 0.42 kg a.i. ha^{-1} paraquat (1,1′-dimethyl-4,4′-bipyridinium) + 0.21 kg a.i. ha^{-1} diuron [*N*′-(3,4-dichlorophenyl)-*N*,*N*-dimethylurea] was applied 7 to 10 d after harvest to prevent seed production and halt soil water use by these weeds. A complete list of field operations and timing for each operation throughout the study is shown in Table 1.

Economic Methodology

The machinery complement of farmer cooperator Ron Jirava was used for cost estimation: a 250-hp John Deere 4wd tractor, 9.1-m-wide Flexi-Coil 6000 no-till drill with attached air cart, 150-hp John Deere 2wd tractor, 24.4-m-wide sprayer with 3200-L-capacity tank, John Deere 8820 combine with 7.3-m cutting platform, single-axle 11-m^3-capacity grain truck, 30-m^3-capacity tractor-trailer semi, one-ton pickup truck, and utility/service vehicle. The age, used or new purchase price,

Table 1. Generalized field operations and inputs for spring-planted wheat, barley, yellow mustard, and safflower at Ritzville, Adams County, WA, 1997–2001.

Date	Wheat	Barley	Yellow mustard	Safflower
15 Mar.†	Herbicide: 0.43 kg a.e. ha^{-1} glyphosate.	Herbicide: 0.43 kg a.e. ha^{-1} glyphosate.	Herbicide: 0.43 kg a.e. ha^{-1} glyphosate.	Herbicide: 0.43 kg a.e. ha^{-1} glyphosate.
4 Apr.‡§	Planted at 78 kg ha^{-1} and fertilized at 40 kg N ha^{-1}, 10 kg P ha^{-1}, and 10 kg S ha^{-1}.	Planted at 78 kg ha^{-1} and fertilized at 40 kg N ha^{-1}, 10 kg P ha^{-1}, and 10 kg S ha^{-1}.	Planted at 8 kg ha^{-1} and fertilized at 40 kg N ha^{-1}, 10 kg P ha^{-1}, and 10 kg S ha^{-1}. Replanted on 29 April in 1998 and 1999 after killing frost.	Planted at 34 kg ha^{-1} and fertilized at 50 kg N ha^{-1}, 11 kg P ha^{-1}, and 11 kg N ha^{-1}. Safflower was discontinued in 2001.
18 May	In-crop broadleaf herbicide: 0.84 kg a.e. ha^{-1} 2,4-D in 1999 and 2000. 2,4-D plus 0.02 L a.i. ha^{-1} thrifensulfuron + tribenuron in 1998 and 2000. 2,4-D plus 0.08 kg a.e. ha^{-1} dicamba in 2001.	In-crop broadleaf herbicide: 0.84 kg a.e. ha^{-1} 2,4-D in 1999 and 2000. 2,4-D plus 0.02 L a.i. ha^{-1} thrifensulfuron + tribenuron in 1998 and 2000. 2,4-D plus 0.08 kg a.e. ha^{-1} dicamba in 2001.		
9 Aug.	Harvest	Harvest	Harvest	
18 Aug.	Postharvest herbicide: 0.42 kg a.i. ha^{-1} paraquat + 0.21 kg a.i. ha^{-1} diuron in 1999, but applied on only 50% of wheat plots in 2001.	Postharvest herbicide: 0.42 kg a.i. ha^{-1} paraquat + 0.21 kg a.i. ha^{-1} diuron in 1999, but applied on only 50% of wheat plots in 2001.	Postharvest herbicide: 0.42 kg a.i. ha^{-1} paraquat + 0.21 kg a.i. ha^{-1} diuron all five years.	
3 Sept.				Harvest
11 Sept.				Postharvest herbicide: 0.42 kg a.i. ha^{-1} paraquat + 0.21 kg a.i. ha^{-1} diuron all four years (1997–2000).

† Dates are the 5-yr average when the specific field operation was conducted. Safflower was discontinued in the study in 2001.
‡ Fertilizer rate was held constant in all crops each year.
§ Plots were sown and fertilized simultaneously in one pass.

size, use, and service life of machinery was considered typical of the area.

Total cost of production was estimated using standard enterprise budgets that identify fixed and variable costs. For a given land and machinery base, fixed costs do not vary with number of hectares planted. Machinery fixed costs are depreciation, interest, taxes, housing, and insurance. Land fixed costs include property taxes and net land rent. Net rent is money paid for rented land or rental income foregone for using owned land. In the study region, net rent is based on the prevailing one-third landlord and two-thirds tenant crop share with the landlord also paying land taxes and one-third of fertilizer expense. Other fixed costs include farm-wide insurance, legal/accounting services, and overhead expenses.

Variable costs include any costs that vary proportionately with the area planted. Machinery repair, fuel, labor, custom hire of services, seed, fertilizer, pesticides, and crop insurance are typical variable costs. The actual operations and input rates for the 5-yr experiment were used in computing variable costs.

Soft white wheat and feed barley prices used in this analysis are \$123.46 and \$92.70 Mg^{-1}, respectively. These are the regional average 1997–2001 farm-gate prices (Washington Agric. Stat. Serv., 2001). Safflower and YM price of \$264.55 Mg^{-1} is the average contract price that regional farmers received during the period.

Net returns include only market returns, excluding government payments or crop insurance indemnities. Although government payments have been and are a very important source of farm income, our study compared rank in market profitability of different rotations, not total farm income. Adding recent predetermined government payments will not change the economic ranking of different treatments. Inclusion of government payments requires assumptions on historic grain yields and base hectarage of individual representative farms. These histories vary from farm to farm, and government programs vary substantially annually and from farm bill to farm bill. Readers may add government payments to base market returns reported here consistent with their particular assumptions if desired.

Net return per rotational hectare is used to correctly measure profitability of different crop rotations. Net returns for each crop year in the rotation are summed and divided by the number of years in the rotation, thereby standardizing all rotations to a 1.0-ha basis. For example, a rotational hectare of WW–SF includes 0.5 ha of WW and 0.5 ha of fallow. This approach also correctly portrays annual income of farmers who commonly allocate $1/n$ of their land to each crop in an n-year rotation. This annual diversification also reduces annual income risk by growing a portfolio of crops and permits more efficient use of machinery and labor over time.

Safflower was discontinued from the 4-yr rotation in 2001, but the remaining crops of the original 4-yr rotation were planted in the original sequence. To permit estimating profitability of the 4-yr rotation for 2001, the profit for SAF was estimated based on its historic yield relationship following YM.

Although WW–SF was not included in the replicated experiment, economic comparison of this traditional system to the experiment's no-till annual spring crop rotations was accomplished by conducting a multiyear grain yield survey of 10 WW–SF farmers within a 7-km radius of the experiment site. A one-page mailed questionnaire with telephone follow-up as necessary was used. The sample size of 10 farmers represents 53% of the original mailing to 19 farmers. The 10 neighboring farmers had climate and soils similar to the experiment site. Of the 10 participating farmers, one reported on three different fields, with varying yields. This farmer's data were added independently, increasing the sample size to 12.

The survey approach permitted observing variation of WW yields over time and over farmers as well as deriving average yields. Reported grain yields from the survey were divided into top, middle, and lower thirds to permit comparisons of each group to spring crop rotations from the experiment. Typical fixed and variable costs for WW–SF were computed from standard enterprise budgets developed for WW–SF for Adams County, WA (Hinman and Esser, 1999).

RESULTS AND DISCUSSION

Variation in annual precipitation had considerable effect on spring crop yields (Table 2). Crop-year (1 Sept. to 31 Aug.) precipitation was 515, 282, 200, 231, and 203 mm for 1997, 1998, 1999, 2000, and 2001, respectively. The 5-yr average annual precipitation of 286 mm was near the long-term average of 292 mm. Substantial variation in year-to-year precipitation is common in the region and underscores the importance of several years of data to accurately compare cropping systems. Yellow mustard exhibited relatively high yield variation, with a standard deviation (SD) of 0.58 vs. a mean of 0.61 Mg ha^{-1}. Grain yield of YM ranged from 1.6 Mg ha^{-1} in 1997 to 0.12 Mg ha^{-1} in 1999 (Table 2). Safflower displayed relatively low yield variation with a SD of 0.38 and a mean of 1.00 Mg ha^{-1}. We theorize that SAF experienced lower yield variation because it extracted soil water below the 150-cm depth (data not shown) with its long taproot. Although deep overwinter soil water recharge is rare, recharge occurred to a depth of 180 cm or greater during the wet 1996–1997 winter (data not shown). Spring wheat does not extract soil water below 150 cm; thus, residual water below 150 cm was available to SAF during the first 3 yr of the study.

Exceptionally high precipitation in the 1997 crop year resulted in high yields for all crops, but yields of all

Table 2. Crop yields from three spring-planted crop rotations and crop-year precipitation from 1997–2001.

Rotation/crop-year precipitation		1997	1998	1999	2000	2001	5-yr avg.	SD
1. Four year					Mg ha^{-1}			
	Safflower	1.59	0.81	1.17	0.67	0.79†	1.00	0.38
	Yellow mustard	1.60	0.38	0.12	0.55	0.39	0.61	0.58
	Wheat	4.29	2.76	1.82	2.69	0.54	2.42	1.38
	Wheat	3.89	2.49	1.68	2.56	0.40	2.21	1.28
2. Two year								
	Wheat	4.36	2.69	1.88	2.96	0.81	2.54	1.32
	Barley	5.16	2.53	1.70	2.91	0.78	2.62	1.64
3. Continuous wheat		4.30	2.76	1.82	2.89	0.94	2.54	1.26
					mm			
Crop-year precipitation		515	282	200	231	203	286	132

† Safflower yield in 2001 is estimated using its historical relationship to yellow mustard.

Table 3. Grain yields for winter wheat–summer fallow from 1997–2001 as reported by farmers within a 7-km radius of the cropping systems experiment site.

Farmer I.D.	1997	1998	1999	2000	2001	SD	Average
	Mg ha^{-1}						
1	5.04	4.64	4.44	4.10	2.56	0.95	4.16
2	4.91	4.64	3.50	4.64	3.09	0.81	4.16
3a†	6.12	3.16	4.44	3.83	2.82	1.30	4.08
3b†	4.84	3.97	3.70	3.77	2.22	0.95	3.70
3c†	4.17	3.63	3.56	3.70	2.62	0.56	3.54
4	6.19	4.24	4.10	5.11	3.09	0.96	4.55
5	3.36	3.36	4.37	3.70	2.02	0.85	3.36
6	4.03	3.97	3.23	3.90	1.88	0.91	3.40
7	5.11	3.50	4.03	4.64	2.49	1.02	3.95
8	4.71	3.77	3.90	3.63	2.29	0.87	3.66
9	5.18	3.36	3.56	4.44	2.42	1.06	3.79
10	4.71	4.24	3.83	3.56	1.14	1.39	3.50
Upper one-third	5.65	4.44	4.34	4.71	2.91	0.99	4.41
Middle one-third	4.88	3.83	3.87	3.90	2.44	0.89	3.78
Lower one-third	4.07	3.35	3.46	3.65	1.82	0.87	3.27
Range	3.36–6.19	3.16–4.64	3.23–4.44	3.56–5.11	1.14–3.09		
SD	0.80	0.50	0.69	0.83	0.54	0.98‡	
Average	4.86	3.87	3.89	4.09	2.39		3.82‡

† Farmer no. 3 reported yields on three separate fields.
‡ These statistics apply to the entire data set.

crops except SAF fell sharply during the low-precipitation years. For example, SB yield fell 85%, from 5.16 Mg^{-1} ha in 1997 to 0.78 Mg^{-1} ha in 2001. Wheat following oilseeds in the 4-yr rotation fared the worst of all crops in 2001, yielding only 0.54 and 0.40 Mg ha^{-1}.

Results of a 1997–2001 WW–SF farmer survey are shown in Table 3. Yields of WW–SF were obtained from farms within a 7-km radius of the study site for the spring crop yields reported in Table 2. Soils of the surveyed farms are similar in texture and depth to the study site and are all classified as Ritzville silt loam (Lenfesty, 1967). The weather station at the experiment site was located at the center of the 7-km radius and is considered representative of the surveyed farms. Like the spring crop yields in Table 2, WW yield varied with annual precipitation. Highest yields were recorded in 1997 when precipitation was almost double the long-run average, and lowest yields occurred during the 2001 drought year. Over all farms and years, reported WW yields averaged 3.82 Mg ha^{-1} with a SD of 0.98 Mg ha^{-1}. Average 5-yr yields ranged from 3.36 (Farmer 5) to 4.55 (Farmer 4) Mg ha^{-1}. Yield variation among farms is likely due to management and possibly minor differences in microclimate. Annual average WW yields ranged from 2.39 to 4.86 Mg ha^{-1}. Comparison of Tables 2 and 3 reveal somewhat less annual yield variation over 1997–2001 in surveyed WW–SF yields than in the experiment's spring crop yields. Dividing the WW–SF farmers into upper, middle, and lower thirds gives average yields of 4.41, 3.78, and 3.27 Mg ha^{-1}. Standard deviation ranged from 0.87 to 0.99 Mg ha^{-1} and is positively correlated with average yields.

Table 4 shows annual net returns per rotational hectare for all no-till spring crop rotations and for the different yield groups of surveyed WW–SF farmers. Five-year averages and SDs of net returns are also reported for each rotation. The WW–SF survey results were excluded from formal statistical comparisons of mean profitability because the survey results were not part of the replicated randomized complete block design of the experiment. Since the surveyed farmers represented over 50% of the population of all WW–SF farmers within a 7-km radius of the experiment, WW–SF average returns are treated informally as point estimates of the population means for this group of neighbors. Statistical comparisons of SDs of profitability between the spring crops and WW–SF were not possible, but these SDs permit useful informal comparisons of the economic riskiness of the different cropping systems.

Among the spring crop rotations, continuous no-till

Table 4. Comparison of net returns over total cost across 5 yr for three continuous annual no-till spring crop rotations and for winter wheat–summer fallow.

Rotation†	1997	1998	1999	2000	2001	1997–2001 Average	1997–2001 SD
	$ per rotational hectare						
Spring crops exp.							
SAF–YM–SW–SW	124.27	−36.97	−83.94	−57.03	−103.58‡	−31.45a§	90.69
SW–SB	141.84	5.96	−55.45	−12.06	−140.77	−12.10ab	103.02
Continuous SW	156.69	43.02	−36.45	13.84	−116.53	12.11b	100.97
Surveyed farms							
WW–SF average	64.52	23.75	24.49	32.39	−37.53	21.52	36.97
WW–SF upper one-third	96.89	46.97	42.77	58.09	−15.99	45.75	40.60
WW–SF middle one-third	65.01	22.02	23.50	24.73	−35.31	19.99	35.78
WW–SF lower one-third	31.65	2.00	6.84	14.46	−61.01	−1.21	35.26

† SAF, safflower; YM, yellow mustard; SW, soft white spring wheat; SB, spring barley; WW, winter wheat; SF, summer fallow.
‡ 2001 safflower net return is estimated using its historical relationship to yellow mustard.
§ Average net returns followed by same letter are not significantly different. $LSD_{0.05}$ for spring-planted rotations is $31.16 ha^{-1}.

SW had the highest average net return at $12.11 ha^{-1} yr^{-1} followed by SW–SB and SAF–YM–SW–SW at −$12.10 and −$31.45 ha^{-1} yr^{-1}, respectively (Table 4). An $LSD_{0.05}$ of $31.16 ha^{-1} yr^{-1} indicates that the 4-yr rotation was significantly less profitable than continuous SW. In addition, continuous SW exceeds SW–SB in mean profitability at the $LSD_{0.10}$ level. Using this LSD to compare SW with WW–SF, with (assumed population) mean of $21.52 ha^{-1}, indicates equivalent net returns (Table 4). However, the top one-third of WW–SF farmers exceeded the average profit for continuous annual SW. Equivalent average profitability between no-till annual SW and WW–SF is a welcome result given the −$96 ha^{-1} yr^{-1} shortfall in profitability of previous research comparisons of no-till HRSW with WW–SF.

The WW–SF system also was the least risky rotation over 1997–2001 with a SD of $36.97 ha^{-1} yr^{-1} compared with $90.69 for SAF–YM–SW–SW, $100.97 for continuous SW, and $103.02 for SW–SB (Table 4). Farmers and lenders generally prefer cropping systems that sustain profitability and reduce economic risk. Results show that during 1997–2001 WW–SF had this advantage.

Low relative variance of SAF–YM–SW–SW is attributable to consistently negative, but slightly more uniform, net returns throughout the study period. In contrast, the other two spring crop rotations enjoyed positive net returns in 1997, 1998, and 2000 (Table 4). Yields in Table 2 drive the annual profit variation in Table 4. Drought-depressed yields in 1999 and 2001 decreased average profitability and increased the economic riskiness of the three spring crop rotations (Table 4). While net returns for WW–SF were not immune from the 1999 and 2001 drought years, this rotation was able to withstand yield reductions to a greater extent compared with annual spring cropping, especially in 1999.

The upper, middle, and lower thirds of the WW–SF survey showed average net returns over total costs per rotational hectare per year of $45.75, $19.99, and −$1.21, respectively. Under the possibly untenable assumption that continuous SW yields could hold at average levels on the lower third of WW–SF farms, then continuous SW would exceed the estimated average profitability of WW–SF by $13.32 ha^{-1} yr^{-1} [$12.11 − (−$1.21)] on these farms.

SUMMARY AND CONCLUSIONS

The most promising result of this study was that continuous annual no-till SW was economically competitive with traditional WW–SF. Results may be somewhat robust considering that the 5-yr study contained 4 yr of below-average precipitation and two major drought years. Two previous multiyear studies in east-central Washington showed that no-till HRSW lagged WW–SF by $113 ha^{-1} yr^{-1}.

Continuous no-till SW showed considerably more economic risk compared with WW–SF. Future production and breeding research should focus on improving the yield stability of spring wheat under variable precipitation. Targeted agricultural policies such as green payments for no-till farming in areas vulnerable to wind erosion could also help tip the scale toward adoption of these soil-conserving cropping systems. Subsidized crop insurance for farmers adopting no-till could also reduce their economic risk. A negative 116.53 ha^{-1} net return for SW, as evidenced in 2001, is an unacceptable risk for most farmers, even if long-run average prospects are positive.

Given the potential for continuous annual no-till SW to markedly reduce dust emissions compared with WW–SF, the equivalent profitability of these two systems provides the first reported potential win-win solution for no-till farmers and the environment in the low-precipitation zone of the inland PNW.

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