BEST MANAGEMENT PRACTICES FOR SUMMER FALLOW IN THE WORLD'S DRIEST RAINFED WHEAT REGION

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By
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Abstract

The Horse Heaven Hills (HHH) located in south-central Washington contains the world’s driest rainfed wheat production region where farms receive as little as six inches average annual precipitation. Late summer establishment of winter wheat into carryover seed-zone water after a year of fallow is essential to achieve the highest grain yield potential. Tillage of fallow land during the spring is considered necessary to retain adequate seed-zone water during the dry summer months, but blowing dust from excessively tilled fallow is a major safety, environmental, and soil quality concern.

The objective of this 5-year study was to compare the effects of three fallow management systems on soil water dynamics, wheat stand establishment, grain yield, and economic returns on two farms in western and eastern portions of the HHH where long-term annual precipitation averages 6.0 and 8.3 inches, respectively. Fallow management treatments were: traditional tillage (TTF), undercutter tillage (UTF), and no-tillage (NTF). This publication documents that NTF in the western HHH and UTF in the eastern HHH are best management practices for farmers and the environment in a region where wind erosion from excessively tilled soils is a severe problem.

Soils in the HHH are highly vulnerable to wind erosion due to the dry environment, high winds, limited straw cover, and intensive tillage during fallow. These soils contain high quantities of PM10-sized particulates (i.e., less than 10 micrograms in diameter) that, when exposed, are readily transmitted hundreds of miles in the air stream by suspension (Sharratt et al. 2007). Major dust storms may occur several times a year (Sharratt and Edgar 2011). Exceedances of the US Federal Air Quality Standard for PM10 occurred 20 times between 2000 and 2010 in the city of Kennewick, WA, which is located immediately downwind of the HHH (Sharratt and Edgar 2011). The highest daily PM10 concentration measured in Kennewick during this time period was nearly ten times the concentration allowed by law. All of these PM10 exceedances were attributed to windblown dust.

Abbreviations

HHH – Horse Heaven Hills

TTF – traditional tillage fallow

UTF – undercutter tillage fallow

NTF – no-tillage fallow

HRW – hard red winter wheat

Introduction

Wheat is produced on 300,000 rainfed acres in the HHH region in south-central Washington (Figure 1). The western portion of the HHH receives as little as 6.0 inches average annual precipitation. An annual average of 8.3 inches of precipitation falls in the eastern portion. Farmers practice a 2-year tillage-based winter wheat-summer fallow rotation. Given the low precipitation, wheat grain and straw production are generally modest to low (Papendick 2004).

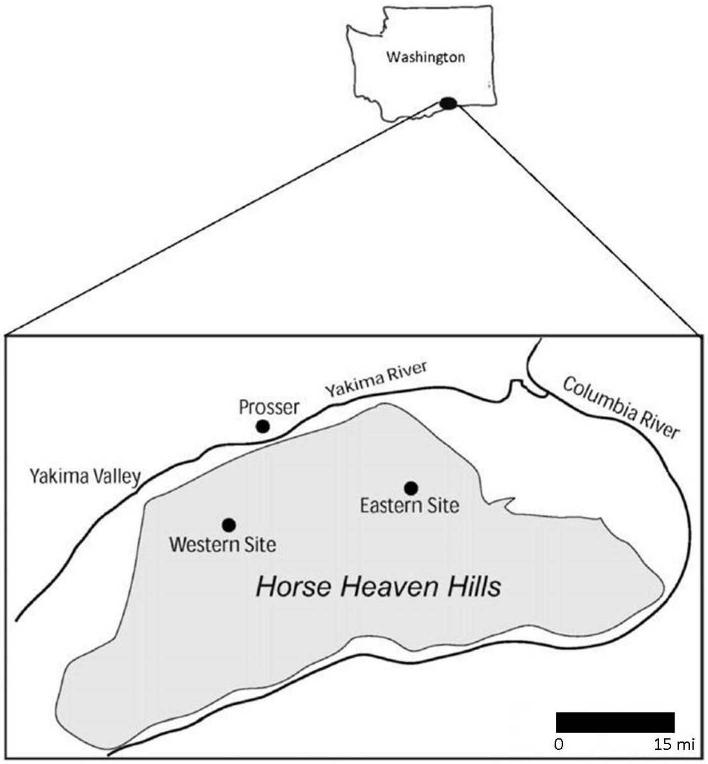

Figure 1. Location of the Eastern and Western sites in the HHH. Map courtesy of B.S. Sharratt, USDA-ARS.

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NTF for control of erosion is successfully used in many regions of the world, but it is not yet practiced by most farmers in the low-precipitation winter wheat-summer fallow zone in the Pacific Northwest (PNW) because of seed-zone drying during the summer. Instead, most farmers till the soil during the spring of the fallow year to break soil capillary continuity to best retain seed-zone water (Hammel et al. 1981; Wuest 2010) in order to plant winter wheat in late August-early September for highest grain yield potential.

Farmers and scientists have long had interest in the feasibility of continuous annual (i.e., no fallow year) no-till cropping of spring wheat and other potential crops in this dry region. A 6-year experiment conducted in the western HHH to test this concept showed that although production of continuous annual no-till spring wheat provided clear environmental advantages, it was not economically competitive with the tillage-based winter wheat-summer fallow system (Schillinger and Young 2004).

UTF, where narrow-pitched V-shaped sweep blades are used to slice beneath the soil surface to sever capillary pores with minimum soil lifting, has shown excellent agronomic potential (Papendick 2004) and has been proven to significantly reduce blowing dust emissions compared to TTF (Sharratt and Feng 2009).

The objective of this study was to compare the effects of three fallow management systems on soil water dynamics, wheat stand establishment, grain yield, and economic returns.

Materials and Methods

Overview

A 5-year summer fallow management field experiment was conducted from 2006 to 2011 at two locations in the HHH, denoted as Western and Eastern sites. Precipitation during the study period for the two sites was recorded at two meteorological stations of WSU’s AgWeatherNet. Station McKinley Spring is located 0.6 miles north of the Western site and Station Carlson is located 0.4 miles northeast of the Eastern site. Annual crop year (Sept. 1–Aug. 31) precipitation during the study period ranged from 5.3 to 8.1 inches and averaged 6.5 inches at the Western site (Table 1). At the Eastern site, crop year precipitation during the study ranged from 6.6 to 9.9 inches and averaged 8.5 inches (Table 1). The distance between the two sites is 30 miles.

Table 1. Crop year (Sept. 1–Aug. 31) precipitation (inches) at two experimental sites from 2005 to 2011 in the HHH.

	Western site						Eastern site					
Month	2006*	2007	2008	2009	2010	2011	2006	2007	2008	2009	2010	2011
Sept.	0.71	0.68	0.14	0.20	0.05	1.32	0.79	0.51	0.44	0.12	0.10	1.06
Oct.	0.17	0.84	0.28	0.20	0.85	0.78	0.46	0.52	0.64	0.19	1.04	0.88
Nov.	0.33	1.12	0.49	0.66	0.18	0.56	0.67	1.82	0.78	0.93	0.38	1.25
Dec.	2.59	0.73	1.78	0.67	0.39	1.87	2.41	1.79	1.21	0.89	0.38	1.95
Jan.	1.63	0.15	1.03	1.15	1.50	0.85	1.84	0.81	1.49	1.01	1.86	0.50
Feb.	0.35	0.69	0.41	0.95	0.59	0.25	0.45	0.76	0.65	1.05	0.71	0.30
Mar.	0.53	0.19	0.39	0.44	0.23	1.08	0.68	1.03	0.49	0.98	0.26	1.38
Apr.	0.77	0.35	0.05	0.30	0.41	0.33	1.65	0.43	0.21	0.27	0.75	0.54
May	1.11	0.17	0.23	0.59	2.00	0.83	1.28	0.40	0.40	0.90	1.97	1.80
June	1.21	0.80	0.43	0.22	0.95	0.26	1.15	1.13	0.80	0.21	1.71	0.27
July	0.02	0.01	0.00	0.00	0.12	0.05	0.00	0.02	0.00	0.05	0.18	0.00
Aug.	0.01	0.29	0.08	0.03	0.16	0.00	0.00	0.12	0.20	0.00	0.11	0.00
Total**	9.43	6.02	5.31	5.41	7.43	8.18	11.38	9.34	7.31	6.60	9.45	9.93

*The 2006 data are shown because this was the fallow year (i.e., Sept. 1, 2005–August 31, 2006) prior to planting wheat in the first year of the experiment.

**The 5-year average crop year precipitation was 6.47 inches at the Western site and 8.53 inches at the Eastern site.

Soils

Soil at the Western site is a Warden silt loam. These soils have a mantel of loess over lacustrine sediments that were deposited by soil sediments suspended in water during the massive, cataclysmic outburst floods that occurred during the last ice age about 15,000 years ago following the sudden rupture of the ice dam that contained Glacial Lake Missoula (Rasmussen 1971; Sweeney et al. 2005). Soil at the Eastern site is a Ritzville silt loam. Ritzville soils were formed in loess. Both sites were characterized by a slope of less than 2% and soil depth of more than six feet.

Establishment of Tillage Treatments

The TTF, UTF, and NTF treatments were established from 2006 through 2010 at both the Western and Eastern sites. Different parcels of land were used every year, but the location of experiment plots were kept within a 2-mile radius during the five years at both sites to reduce within-site soil variability. The experimental design was a randomized complete block with four replications. Individual plot size was 200 x 60 ft to accommodate the use of commercial-size farm equipment. Wheat residue was always left standing and undisturbed from harvest in July through the winter. For all treatments, glyphosate herbicide was applied in March or early April at rates that averaged 10 oz/acre at the Western site and 16 oz/acre at the Eastern site.

In the TTF treatment, the soil was tilled with a tandem disk to a depth of 5 inches in April. A 5-year average of 14 lb/acre aqua NH_3-N at the Western site and 48 lb/acre of aqua NH_3-N at the Eastern site was injected into the soil with shanks spaced 12 inches apart in May or June.

For UTF, an undercutter sweep implement equipped with overlapping 32-inch-wide V blades on two ranks (Figure 2) was used to slice beneath the soil at a depth of 5 inches and simultaneously deliver aqua NH_3-N fertilizer with minimum soil lifting or disturbance of surface residue. Application rates of aqua NH_3-N for UTF were identical to those of TTF as described above. The soil was subsequently rodweeded an average of two times at both locations for both TTF and UTF at a depth of 4 inches in June and again in July or August to control Russian thistle and other broadleaf weeds.


Figure 2. An undercutter implement with V-shaped blades being used for primary spring tillage plus fertilizer injection during the spring of the fallow year. Scientists and farmers have conclusively shown that use of the undercutter implement for primary spring tillage effectively retains equal seed-zone and total profile soil water and significantly greater surface residue compared to TTF implements, such as a tandem disk or field cultivator. Photo by W.F. Schillinger, WSU.

The stubble remained standing and the soil undisturbed throughout the fallow period in the NTF treatment. Weeds in NTF were controlled with two to four herbicide applications from March to August. Herbicides used were glyphosate or tank mixtures of glyposhate + dicamba or paraquat + diuron. A 5-year average of 19 lb/acre of anhydrous NH_3-N at the Western site and 41 lb/acre N as Solution 32 (NH_4NO_3 + urea) at the Eastern site was applied at time of planting with the drill in the NTF treatment.

Planting

Hard red winter wheat (HRW) varieties were selected for use by both cooperating farmers. The same variety was used for planting of all three fallow management treatments within a given site and year. Seeding rate for early planting in the TTF and UTF at the Western site (only possible in 2006; conducted on Sept. 6) was 20 lb/acre. Early planting of HRW (dates ranged from Aug. 26 to Sept. 7) was possible all five years for TTF and UTF at the Eastern site and average seeding rate was 29 lb/acre. Early planting at both sites was conducted with an International Harvester 150 deep-furrow drill with 18-inch row spacing.

For NTF, seed at the Western site was “dusted in” at a shallow (one inch) depth with a no-till disc drill on 10-inch row spacing in the first half of October, before the onset of fall rains, at an average seeding rate of 41 lb/acre. In years two through five, late planting of TTF and UTF took place on the same date as that for NTF. At the Eastern site, planting of NTF was conducted with a no-till disc drill on 10-inch row spacing at a depth of one inch in the first half of November, generally after the onset of fall rains, at an average seeding rate of 60 lb/acre.

Field Measurements

In late March and again in late August during fallow from 2006 to 2010, soil volumetric water content in the 1- to 6-foot depth was measured in 6-inch increments. Additionally, seed-zone volumetric water content was determined in late August in 1-inch increments to a depth of 10 inches with an incremental soil sampler for all plots at both sites.

Wheat plant stand establishment was assessed by counting individual plants in 3-foot-long row segments in March. Grain yield was determined in mid-July each year by harvesting a 5-foot-wide swath through each 200-foot-long plot with a plot combine (Figure 3).

Economic Assessment

Enterprise budgets were constructed to assess the profitability and cost of the three fallow systems at both sites. Costs were divided into variable and fixed categories. The former vary by the number of acres farmed. These include fertilizer, herbicides, seed, fuel, machine rental, machinery repairs and maintenance, and labor. Fixed costs include depreciation, interest, property taxes, housing, and insurance on machinery. Land is also traditionally included as a fixed cost. Land cost equals the cash or share rent for land and property taxes. Total economic costs include a market return for the farmer’s land, machinery, and labor. Total economic budgeting permits comparing production systems on an “apples to apples” basis even though different farmers may acquire their labor, machinery, and land by different methods.

Figure 3. Harvesting HRW in the experiment at the Western site in 2008. The grain yield of this crop was 16 bushels/acre, slightly less than the long-term average for winter wheat after summer fallow at this site. Despite modest grain yield potential, wheat farming in this environment can be profitable if variable costs are kept low and farm acreage is large. Photo by S.E. Schofstoll, WSU.

The study uses a 2009–2013 average regional farm gate price of $7.09/bushel for HRW (Union Elevator 2013). A recent multi-year average crop price is superior to using actual prices for each experimental year to avoid misrepresentation as might happen if one fallow system happened to produce a high yield concurrent with a wheat price spike. Gross returns also include government direct and counter cyclical payments and a farmer’s historic grain yield. The 5-year experiment grain yield for HRW following TTF was used for each site’s historic yield.

Data Analysis

Analysis of variance was conducted for: (i) water lost from the 6-foot soil profile between late March and late August, (ii) volumetric water content at 6-inch increments throughout the 6-foot soil profile in late August, (iii) volumetric seed-zone water content in one-inch increments to a depth of 10 inches in late August, (iv) plant stand establishment, (v) HRW grain yield, (vi) variable costs, (vii) fixed costs, (viii) total costs, (ix) gross returns, and (x) net returns. All analyses of variance tests were done at the 5% level of significance.

Results and Discussion

Water in the Six-Foot Soil Profile

Soil water content of the three treatments measured at the end of August in the 0- to 3-foot depth as well as the complete 0- to 6-foot profile at both sites averaged over the five years is shown in Table 2 and Figure 4. At the Western site, March to August water loss was 1.4, 1.4, and 1.7 inches from the upper 3 feet of soil in the TTF, UTF, and NTF treatments, respectively; these differences being highly statistically significant. The same water loss trend among treatments occurred in the upper 3 feet at the Eastern site with NTF losing significantly ($p < 0.001$) more than the other treatments (Table 2). At both sites, the majority of water loss from March to August occurred from the upper 3 feet rather than from below this depth (Figure 4). Essentially no water loss occurred from below 3 feet with NTF at either site whereas, with TTF and UTF, some loss occurred at the Western site and, conversely, some water was gained below 3 feet at the Eastern site (Table 2; Figure 4). In the entire 6-foot profile, there were no differences in water content among treatments at the Western site but a highly significant lower water content for NTF at the Eastern site (Table 2). Averaged over the five years, NTF had significantly less water in late August than both TTF and UTF to a depth of 18 inches at the Western site and significantly less water than either or both TTF and UTF at every sampling increment to a depth of 42 inches at the Eastern site (Figure 4). These data provide the first documentation of such deep over-summer soil drying from NTF compared to tillage-based summer fallow in the PNW.

Table 2. Soil water content during fallow in late March and again in late August (before planting) and associated soil water loss during this 5-month period with TTF, UTF, and NTF systems averaged over five years at two on-farm locations in the HHH.

	Timing in fallow period		
	Spring (late March)	Planting (late August)	March to August water loss*
	Soil water content (inches)		
		Western site	
Top 3 feet**			
TTF	5.87	4.49	1.38 b
UTF	5.87	4.49	1.38 b
NTF	5.87	4.17	1.70 a
p-value			< 0.01
Complete 6 feet			
TTF	11.34	9.72	1.62
UTF	11.34	9.84	1.50
NTF	11.34	9.61	1.69
p-value			ns
		Eastern site	
Top 3 feet			
TTF	5.75	4.13	1.62 b
UTF	5.75	4.33	1.42 b
NTF	5.75	3.82	1.95 a
p-value			< 0.001
Complete 6 feet			
TTF	8.82	7.56	1.26 b
UTF	8.82	7.56	1.26 b
NTF	8.82	6.85	1.97 a
p-value			< 0.001

*Within-column water loss means at each site followed by a different letter are significantly different at $p < 0.05$. ns = no significant difference.
**The upper portion of the data at each site shows water content in the top 3 feet of soil and the bottom portion shows water content in the entire 6-foot soil profile.

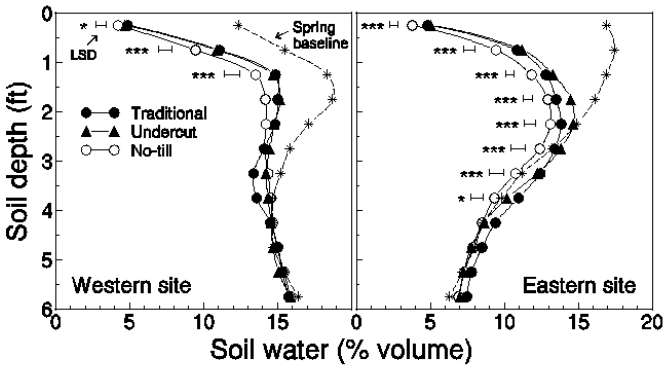

Figure 4. Soil volumetric water content measured in 6-inch increments to a depth of 6 feet in late August for three fallow management systems at the two experiment sites in the HHH. Data points are the mean values for the 5-year experiment. Significant differences at the 0.05 and 0.001 probability levels are indicated by * and ***, respectively. The early spring baseline soil water content (dotted line with asterisks) was not included in the statistical analysis. Width of horizontal bars shows least significant differences (LSD) for each depth increment.

Seed-Zone Water in Late August

Volumetric water content in the seed zone was markedly lowest for NTF in all five years and when averaged over years at both sites (Figure 5). Highly significant ($p < 0.001$) reductions in seed-zone water with NTF compared to TTF or UTF occurred in every 1-inch measurement increment from 4 inches to 10 inches at both sites. This drying of the seed zone in NTF during the warm, dry summer months is consistent with the findings of numerous other studies on this topic from the PNW (Hammel et al. 1981; Wuest 2010; Wuest and Schillinger 2011).

There were no seed-zone volumetric water differences between TTF and UTF at any sampling increment at the Western site (Figure 5), but at the Eastern site, UTF had significantly less water than TTF at the five increments between the 4- and 7-inch depths. These 5-year average differences between TTF and UTF at these sampling depths at the Eastern site are due to

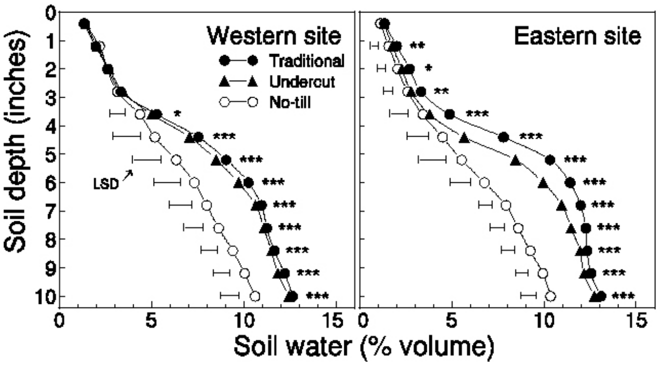

Figure 5. Seed-zone volumetric water content in 0.8-inch increments in three fallow management systems measured in late August at the two experiment sites in the Horse Heaven Hills, WA. Data points are mean values for the 5-year experiment. Significant differences at the 0.05, 0.01, and 0.001 probability levels are indicated by *, **, and ***, respectively. Width of horizontal bars shows least significant difference (LSD) for each depth increment.

large differences measured during the first two years of the study (data not shown) when the farmer cooperator was still getting used to, and adjusting, his new undercutter implement to achieve consistent depth control. Consequently, the UTF tillage mulch at the Eastern site was somewhat less than the desired 5-inch thickness during the first two years of the study, but uniform depth in this treatment was achieved in the final three years during which time no seed-zone water differences between TTF and UTF occurred. This is consistent with findings of long-term research (Papendick 2004) as well as testimonials from 47 farmers throughout the low-precipitation region (Young and Schillinger 2012) who compared TTF and UTF and observed no differences in seed-zone water or winter wheat grain yield between the two.

Planting and Stand Establishment

Early planting of HRW into the TTF and UTF treatments at the Western site was only possible during the first year of the study after 9.5 inches of precipitation occurred during the 2006 (Sept. 1–Aug. 31) fallow year (Table 1), which is 158% greater than the long-term average precipitation for this site. In the other four years of the study, seed-zone water conditions were too dry for early planting (Figure 5). Early planting of NTF was not possible in any year.

At the Eastern site, seed-zone water was adequate for early planting of TTF and UTF for all five years. Stand establishment in TTF and UTF was adequate all years except in 2009 when a crusting rain occurred after planting but before seedling emergence, resulting in spotty stands that necessitated replanting. The seed zone of NTF was too dry for early planting in all years of the study (Figure 5).

Wheat Grain Yield

Grain yield of HRW by fallow systems for the five years as well as the 5-year yield average are shown for both sites in Table 3. At the Western site, there were no differences in grain yield between TTF and UTF, except in 2011 when UTF produced 34% more grain than TTF. We have no explanation for this yield difference in 2011 as both of these treatments had equal amounts of stored soil water before planting and seed was “dusted in” on the same day. This boost in grain yield in 2011 resulted in UTF producing significantly greater grain yield compared to TTF when averaged over the five years (Table 3). Grain yield for NTF was equal (2008), almost equal (2007), less than (2009 and 2010), and greater than (2011) that of the TTF and UTF treatments (Table 3). Grain yield of NTF far exceeded UTF, and especially TTF, in 2011. We, again, have no clear explanation for this phenomenon as there were no differences among treatments for total soil water in the 6-foot soil profile in fallow in late August 2010 and treatments were all planted on the same date. We speculate that residue cover may have been a factor since grain yield was NTF > UTF > TTF ($p < 0.001$) in 2011. These treatment differences were also visibly obvious in all four replicates at time of harvest. Averaged over the five years, UTF produced the highest grain yield, followed by NTF and TTF (Table 3). Although these 5-year grain yield treatment differences were highly significant ($p < 0.001$), the spread from highest to lowest average yield was only 2.3 bushels/acre.

At the Eastern site, there were no grain yield differences between TTF and UTF in any year, and the 5-year average grain yield for these two treatments was essentially identical (Table 3). This further confirms the observations of 47 regional famers who reported no agronomic differences in the TTF and UTF methods for winter wheat-summer fallow farming (Young and Schillinger 2012). Grain yield of NTF was significantly less than the other two treatments in all years except 2010, which was the crop year when soil crusting caused by rain showers necessitated replanting of TTF and UTF (i.e., all three treatments were therefore planted on the same day in mid-November). Averaged over the five years, the late-planted NTF grain yield was only 69% of that for TTF and UTF (Table 3).

Economics

At the Western site, UTF earned net returns of $41/acre (Table 4). TTF and NTF trailed at $31 and $30/acre, respectively, but there were no statistically significant differences among the three fallow systems (Table 4).

Table 3. Grain yield of HRW for three fallow management systems for five years as well as the 5-year average at two locations in the HHH.

	Year					
	2007	**2008**	**2009**	**2010**	**2011**	**5-year average**
	Grain yield* (bushels/acre)					
	Western site					
TTF	26 ab	16	18 a	27 a	27 c	23 b
UTF	28 a	16	17 a	23 a	36 b	24 a
NTF	25 b	16	12 b	18 b	42 a	23 b
p-value	< 0.05	ns	< 0.01	< 0.05	< 0.001	< 0.001
	Eastern site					
TTF	48 a	26 a	28 a	20	39 a	32 a
UTF	48 a	27 a	27 a	20	38 ab	32 a
NTF	32 b	7 b	23 b	17	33 b	22 b
p-value	< 0.001	< 0.001	< 0.01	ns	< 0.05	< 0.001

*Within-column winter wheat grain yield means at each site followed by a different letter are significantly different. ns = no significant difference at $p < 0.05$.

Table 4. Mean variable, fixed and total costs, and gross and net returns ($/acre) over five years for three fallow management systems at two sites in the HHH.

	Costs			Returns		
	Variable costs	**Fixed costs**	**Total costs**	**Gross returns**	**Net returns**	**CV* (%)**
Western site**						
TTF	57.86	74.55	132.40 b	163.45	31.04	55
UTF	58.40	80.62	139.02 a	180.04	41.02	75
NTF	59.67	78.72	138.40 a	168.84	30.44	152
p-value	ns	ns	ns	ns	ns	
Eastern site						
TTF	90.27 b	110.75 a	201.02 b	241.77 a	40.75 a	130
UTF	88.26 b	111.16 a	199.42 b	240.21 a	40.79 a	126
NTF	121.87 a	87.56 b	209.44 a	172.29 b	–37.15 b	88
p-value	< 0.001	< 0.01	ns	< 0.01	< 0.001	

*CV = Coefficient of variation for net returns.
**Within-column means at each location followed by a different letter are significantly different. ns = no significant difference at $p < 0.05$.

At the Eastern site, TTF and UTF achieved identical net returns of $41/acre (Table 4). The equal profit corresponded to equal grain yields of 32 bushels/acre for these systems (Table 3). NTF at the Eastern site lagged sharply in net returns as did grain yield (Tables 4 and 3).

To provide a deeper understanding of the profit results, we analyzed gross returns and cost components for the fallow systems and sites as displayed in Table 4. Gross returns are comprised of HRW sales and government payments. Gross returns exceeded the total costs for all fallow systems at the Western site and for all but NTF at the Eastern site. The latter earned a negative net return of –$37/acre (Table 4). A low average grain yield of 22 bushels/acre on NTF at the Eastern site versus 32 bushels/acre from the other two fallow systems was the principal contributor (Table 4). High variable costs, especially herbicides for weed control in NTF, also limited its profit.

The cooperating farmers at the two sites selected their types and rates of herbicides and fertilizers and annual machine operations for the three fallow systems. Table 4 reveals that the cooperating farmer at the Western site exercised more careful cost control. Lower costs were to be expected given the lower grain yield potential for this site, but our analysis suggests that cost control was disproportionately tighter even considering grain yield potential. Reduced fixed costs are a result of calibrating machinery to the available acreage and achieving good efficiency in field operations. Variable cost control reflected adjusting fertilizer and herbicide applications to realistic grain yield expectations at the Western site. The prior experience with NTF by the two cooperating farmers was also likely a factor in choosing inputs. The Western site cooperator had several years of prior experience with NTF and was therefore quite aware of the variable cost effectiveness of various herbicides for control of Russian thistle during warm, dry summer conditions. Conversely, the Eastern site cooperator had little experience with NTF and chose more expensive herbicides and higher application rates in the hopes of achieving the best weed control.

Summary and Management Recommendations

1. At both sites, seed zone (0- to 10-inch depth) water as well as water in the surface 3 feet of soil was consistently and significantly lower in NTF compared to the tilled fallow treatments.
2. Seed-zone water was not adequate for early (late August) planting in any fallow management treatment in 4 of 5 years at the drier Western site. Early planting was possible every year with TTF and UTF at the Eastern site.
3. The UTF treatment had the highest average grain yield at the Western site, and there were no average grain yield differences between TTF and NTF. At the Eastern site, early-planted TTF and UTF had identical average grain yields while the late-planted NTF yields were only 69% of the other treatments.
4. Despite modest grain yields at the drier Western site, economic net returns were positive for all three fallow management systems due to careful cost management, and there were no significant differences in net returns among treatments. At the Eastern site, net economic returns were identical for TTF and UTF but returns lagged substantially for late-planted wheat on NTF due to low grain yields and high variable costs.

The purpose of this study was to provide the science-based information needed by the USDA-Natural Resources Conservation Service to allow them to formulate farm programs that provide realistic incentives to wheat farmers to change from TTF to UTF or NTF. A major conclusion is that late-planted winter wheat on NTF was equally profitable as the tilled fallow treatments at the Western site. Wide-spread adoption of NTF in the western region of the HHH would, without question, sharply reduce wind erosion, blowing dust, and air quality problems. We are encouraged that some of the leading farmers in the western HHH are adopting NTF over large areas of their farms.

For the eastern HHH, where precipitation is relatively more abundant and where early planting of winter wheat into adequate seed-zone water in tilled fallow is the norm rather than the exception, the UTF method will generate the same grain yields and economic net return and provide much better wind erosion control compared to TTF.

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Schillinger, W.F., and D.L. Young. 2014. Best Management Practices for Summer Fallow in the World’s Driest Rainfed Wheat Region. *Soil Science Society of America Journal* 78: 1707–1715.

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