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Article

Wheat Cultivar Performance and Stability between No-Till and Conventional Tillage Systems in the Pacific Northwest of the United States

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Abstract: In Washington, over fifty percent of the wheat produced under rainfed conditions receives less than 300 mm of annual precipitation. Hence, a winter wheat-summer fallow cropping system has been established to obtain adequate moisture for winter wheat production. Current tilled fallow systems receive significant soil erosion through both wind and water. As a result, no-till chemical fallow systems are being adopted to mitigate erosion concerns. The objective of this study was to evaluate current Pacific Northwest cultivars under no-till chemical fallow and tilled fallow systems to identify cultivars adapted to a late-planted no-till system. Twenty-one cultivars were planted in a split-plot design with fallow type as the main plot and genotype as the sub-plot. Four replications were planted at two locations over three years. Data was collected on heading date, grain yield and grain volume weight. Analysis of variance was conducted on data from each year and location. Results were significant for all traits. Cultivars in the late-planted no-till system yielded an average of 39% less than the tilled fallow system. It is evident that cultivars vary in their adaptability and yield stability across production systems. Chukar and Eltan displayed the highest levels of yield stability, and growers who wish to plant winter wheat in a late-planted no-till system may benefit from choosing these cultivars.

Keywords: *Triticum aestivum* L.; late-planted no-till fallow; tilled fallow; cultivar performance

1. Introduction

Over fifty percent of the wheat (*Triticum aestivum* L.) producing acreage in Washington State receives less than 300 mm of annual precipitation [1]. The majority of this precipitation falls during the winter and early spring. With this limiting amount of precipitation, it is not economically viable for growers to continuously crop their land [2,3]. As a result, growers have adopted a rotation of tilled summer fallow followed by winter wheat. By leaving the ground fallow for a crop cycle, enough moisture is retained (about 30%) from the fallow year to establish and support a crop the following year [4]. Sowing is typically done in late August to early September using split-packers with a hoe-type opener. Seed may be planted more than 150 mm deep to reach adequate moisture for germination [5,6]. If adequate moisture cannot be reached with a deep furrow drill, growers may opt to wait for additional precipitation before planting, but risk losing grain yield [7], or they might seed into soil with insufficient moisture and risk poor stand establishment, which necessitates another planting operation.

Another option for growers in the drier regions is to use a chemical fallow and no-till planting system. Ground is left fallow for a year and weeds are managed with herbicides rather than tillage. In Central Washington, the commonly used no-till drills lack the ability to create deep furrows and place seed in the moisture zone. Deep furrows prevent soil from silting back onto planted seed, which hinders emergence at the typical late August to early September planting time. As a result, planting must be delayed until after fall rainfall events have provided adequate moisture for planting, typically in October or early November. Delayed planting dates reduce the ability of wheat to compete with weeds during spring growth and lead to an increase in weed pressure [8]. Due to its small size, late-planted winter wheat also is more vulnerable to freezing temperatures during the winter [9,10].

The major advantage of a no-till fallow rotation is that more crop residue is left on the soil surface, which reduces soil erosion [11]. Research has also shown no-till cropping systems to increase soil organic carbon [12], earthworm populations [13] and soil permeability [14]. With fewer tillage operations being conducted, chemical fallow and no-till reduce the amount of fuel used by a producer, thereby reducing input costs [15,16]. Unfortunately, in the traditional deep-furrow planting areas of the Pacific Northwest, little research has been conducted to evaluate which cultivars are best suited for a late-planted no-till system.

Given adequate moisture and timely plantings, it is well documented that winter wheat cultivars perform equally well in both conventional and no-till planting systems [13,14,17]. However, in drier areas where limited moisture necessitates the delay of no-till plantings until later in the fall, the performance of current cultivars planted late into no-till fallow is not well known. Flowers *et al.* [18] evaluated the performance of six Pacific Northwest cultivars under delayed planting, but did not use a no-till drill. Other late planting date studies have only evaluated one cultivar, focused on nutrient management rather than cultivar performance or have not been conducted in the late-planted no-till system of the inland Pacific Northwest [19–22]. The purpose of this research was to compare the performance of current Pacific Northwest cultivars under a tilled summer fallow production system and late-planted no-till fallow production system in the dry areas of the Pacific Northwest.

2. Materials and Methods

Three research sites, Kahlotus, WA, Lind, WA and Ritzville, WA, were established on land with a history of winter wheat/summer fallow production. Fertility, tillage and pre-planting weed control was managed by the farmer cooperators with nitrogen and sulfur rates applied equally for both fallow systems (Table 1). Phosphorus was applied at a rate of 34 kg ha^{-1} to the no-till fallow treatments [19,23]. A four-row deep furrow drill (custom fabricated) with split packers and 40.6 cm row spacing was used to plant the tilled fallow plots in August of 2008, 2009 and September of 2010 at a seeding rate of 45 kg ha^{-1} (Table 1). A five-row, no-till drill (custom fabricated) with 25.4 cm row spacing and New Zealand cross-slot openers were used to plant and fertilize in one pass the late-planted no-till fallow plots in November of 2008 and October of 2009 and 2010 (Table 1). Seeding rate for the no-till fallow treatment was 67 kg ha^{-1}. Seeding rates were adjusted between planter types to maintain comparable seed spacing within rows. Plots were planted in a split-plot design, with fallow type as the main plot and genotype as the sub plot. Four replications of each cultivar by fallow type combination were evaluated, and plot dimensions were 1.5 meters by 4.6 meters. Sub plot treatments consisted of eight soft white, four soft white club, seven hard red and two hard white winter wheat cultivars (Table 2). Weeds were controlled during the growing season by herbicides (2,4-D [2,4-dichlorophenoxyacetic acid] ester) and hand removal.

Data were collected on various agronomic characteristics throughout the season. Heading date was measured in Julian days, and plots were deemed headed when 50% of the heads had emerged from the boot (Feekes 10.3; [24]). A mechanical small plot combine (Nurserymaster Classic, Wintersteiger Co., Salt Lake City, UT) was used to harvest plots. Grain yield was measured from seed collected from the combine as grams per plot and reported as kg ha^{-1}. Grain ranged from 9 to 10% moisture when harvested. Grain volume weight was measured using a Seedburo filling hopper and stand (Seedburo Equipment Co., Chicago, IL, USA). Grain volume weight was measured in lb bu^{-1} and reported as kg hL^{-1}.

Statistical analysis of agronomic data was performed using the statistical package SAS V9.1 (SAS Institute, Raleigh, NC, USA). Data from each location were analyzed using PROC GLM and analysis of variance computed. Random effects were location and block, whereas fixed effects were genotype and fallow type. Least significance difference (LSD) was used to calculate differences between cultivars. Heading date and grain yield from each location were analyzed using PROC CORR in SAS to determine the correlation between these two traits. Data for heading date were not collected for the 2009 Kahlotus site and, therefore, not included in the analysis. Grain volume weight was not collected for the 2011 Lind site.

3. Results and Discussion

Analysis of data identified that location and all location interactions were highly significant ($p < 0.0001$); therefore, data were analyzed separately for each location in the study (data not shown). The main effect of fallow type was significant for grain yield ($p < 0.05$) and heading date ($p < 0.001$) at all locations and all years (Table 3). Fallow-type was a significant source of variation for grain volume weight at all locations, except the 2010 Kahlotus site ($p = 0.08$). The main effect of genotype was significant ($p < 0.0001$) for all parameters measured at all locations and in all years. The genotype X fallow-type interaction was a significant source of variation for all parameters and locations, except grain volume weight at the 2010 Kahlotus site ($p = 0.05$) (Table 3).

Table 1. Winter wheat 2008–2010 agronomic data for Kahlotus, WA, Lind, WA and Ritzville, WA under both a conventional tilled fallow and late-planted no-till fallow system.

Location:	**Kahlotus, WA 2009**		**Lind, WA 2010**		**Kahlotus, WA 2010**		**Lind, WA 2011**		**Ritzville, WA 2011**	
Treatment	Tilled fallow	No-till fallow	Tilled fallow	No-till fallow	Tilled fallow	No-till fallow	Tilled fallow	No-till fallow	Tilled fallow	No-till fallow
Date of seeding	Aug-21-2008	Nov-05-2008	Aug-25-2009	Oct-19-2009	Aug-18-2009	Oct-19-2009	Sep-08-2010	Oct-21-2010	Sep-08-2010	Oct-21-2010
Rate of seeding	45 kg ha^{-1}	67 kg ha^{-1}	45 kg ha^{-1}	67 kg ha^{-1}	45 kg ha^{-1}	67 kg ha^{-1}	45 kg ha^{-1}	67 kg ha^{-1}	45 kg ha^{-1}	67 kg ha^{-1}
Fertility (kg ha^{-1})	56N-11S [z]	56N-34P-11S	56N-11S	56N-34P-11S	56N-11S	56N-34P-11S	56N-11S	56N-34P-11S	56N-11S	56N-34P-11S
Precipitation: 9/1 to 8/31	270 mm		244 mm		247 mm		237 mm		330 mm	
Planting depth	140 mm	≤25 mm	165 mm	≤25 mm	152 mm	≤25 mm	130 mm	≤25 mm	130 mm	≤25 mm
Harvest date	Jul-16-2009	Jul-28-2009	Jul-28-2010	Jul-28-2010	Jul-26-2010	Jul-26-2010	Aug-03-2011	Aug-15-2011	Aug-15-2011	Aug-15-2011

[z] N = nitrogen; P = phosphorous; S = sulfur.

Table 2. Winter wheat cultivars evaluated for performance in conventional tilled fallow and late-planted no-till fallow systems.

Variety	**Source**	**Market class** [y]	**Variety**	**Source**	**Market class**
Eltan	PI 536994	SWW	Moro	CItr 13740	Club
Finch	PI 628640	SWW	Bauermeister	PI 634717	HRW
Lewjain	CItr 17907	SWW	Eddy	Westbred	HRW
Madsen	PI 511673	SWW	Farnum	PI 638535	HRW
Masami	PI 634715	SWW	Finley	PI 586757	HRW
Stephens	PI 658243	SWW	Paladin	Syngenta	HRW
Tubbs06	PI 629114	SWW	Buchanan	PI 532994	HRW
Xerpha	PI 645605	SWW	Hatton	CItr 17772	HRW
Bruehl	PI 606764	Club	MDM	PI 634716	HWW
Chukar	PI 628641	Club	Palomino	Syngenta	HWW
Edwin	PI 606765	Club			

[y] Market Class: SWW = soft white winter; Club = soft white winter club; HRW = hard red winter; HWW = hard white winter.

Table 3. Analysis of variance for heading date (Julian), grain yield (kg ha^{-1}) and grain volume weight (kg hL^{-1}) for wheat cultivars grown under tilled fallow and late-planted no-till chemical fallow systems.

	Lind 2010			**Lind 2010**			**Kahlotus 2010**			**Lind 2011**			**Ritzville 2011**		
	Heading Date	**Grain Yield**	**Grain Volume Weight**	**Heading Date**	**Grain Yield**	**Grain Volume Weight**	**Heading Date**	**Grain Yield**	**Grain Volume Weight**	**Heading Date**	**Grain Yield**	**Grain Volume Weight**	**Heading Date**	**Grain Yield**	**Grain Volume Weight**
Source of variation	**Pr > F^z**														
Block	.	0.1303	0.7282	0.0131	<0.0001	<0.0001	0.0831	0.1242	0.1819	<0.0001	<0.0001	.	0.2877	0.117	0.0444
Fallow-type	.	0.0003	0.0075	<0.0001	0.0214	0.001	<0.0001	0.0187	0.0824	0.0006	0.0011	.	0.0008	0.0032	0.0086
Genotype	.	0.0407	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	.	<0.0001	<0.0001	<0.0001
Fallow-type (Block)	.	0.3168	0.1631	0.2692	0.0053	0.0007	<0.0001	0.0095	0.3021	<0.0001	0.0001	.	<0.0001	0.0003	0.1084
Genotype *X* Fallow-type	.	0.5639	0.4957	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0508	0.002	<0.0001	.	<0.0001	<0.0001	<0.0001
C.V	.	22.65	1.85	0.61	12.69	1.07	0.52	25.22	2.10	0.53	16.12	.	0.69	10.19	1.16
R^{2y}	.	0.82	0.75	0.99	0.80	0.94	0.99	0.72	0.69	0.98	0.93	.	0.96	0.87	0.89

^{z} Pr>F =p robability of rejecting the null hypothesis; ^{y} R^2 = coefficient of determination.

Cultivars displayed highly variable yield from year to year, and yields were substantially higher under the tilled fallow production system compared to the late planted no-till production system. The average yield across all cultivars and all years for the tilled and late-planted no-till production systems was 3,632 and 2,219 kg ha^{-1}, respectively (Table 4). The highest yields for both tilled and no-till were observed at the 2011 Ritzville site. The lowest yields for the tilled and no-till systems were observed at the 2010 Kahlotus and 2011 Lind sites, respectively (Table 4). Extensive downy brome (*Bromus tectorum* L.) pressure was observed at the 2010 Kahlotus site and likely contributed to the lower yields in the no-till system. Yields in the no-till system at the 2011 Lind site were severely impacted by a harsh, cold winter with little snow cover to protect immature late planted wheat seedlings. Winterkill was the limiting yield factor at this site. Andrews *et al.* [22] also observed a decrease in winter survival with late planted wheat.

Due to changes in the rank of cultivars between years, and in an effort to clarify cultivar performance, yield data was summarized to show the number of years each cultivar appeared in the top significance group in each production system (Table 5). Chukar and Eltan were the only two cultivars to rank in the top significance group, based on LSD, in all five years of the late-planted no-till fallow system (Table 5). Chukar was the highest yielding cultivar under the no-till system at Lind in 2010 with a yield of 3,576 kg ha^{-1}, whereas Eltan was not the highest yielding cultivar during any of the five years (Table 4). Eltan is the most widely grown soft white wheat cultivar in current tilled production systems. This may be due to the indication that Eltan is a more stable cultivar and does not display dramatic yield swings from year to year. Chukar and Eltan performed well across years in both the tilled and no-till systems, indicating stability over years and systems. Finch and Masami were the only two cultivars to rank in the top significance group in all five years of the conventional tilled fallow production system (Table 5). Neither Finch nor Masami were the top yielding cultivars in any year (Table 4). Both of these cultivars were similar to Eltan and Chukar in the total number of sites, where they were in the top significant yield group (Table 5). The difference is Finch and Masami have high yield stability in the tilled fallow system, whereas Eltan and Chukar have higher yield stability in the late-planted no-till system (Table 5). The need for growers to identify and plant cultivars that, although not necessarily the highest yielding cultivar in the study, provide stability in production is one of the main concerns to establish sustainable production systems in the face of annually varying environments.

Table 4. Grain yield (kg ha^{-1}) of wheat cultivars grown under conventional tilled fallow and late-planted no-till chemical fallow systems.

	Grain Yield									
	Kahlotus 2009		Kahlotus 2010		Lind 2010		Ritzville 2011		Lind 2011	
Entry	Conventional tilled fallow	Late-planted no-till fallow	Conventional tilled fallow	Late-planted no-till fallow	Conventional tilled fallow	Late-planted no-till fallow	Conventional tilled fallow	Late-planted no-till fallow	Conventional tilled fallow	Late-planted no-till fallow
Bauermeister	3,559	1,705	2,315	1,582	3,487	2,727	5,592	4,166	2,577	1,340
Bruehl	3,018	1,384	3,643	1,896	4,047	2,448	6,005	3,591	3,700	1,007
Chukar	3,159	1,130	4,529	2,396	4,287	3,576	5,987	4,025	3,660	1,436
Eddy	3,117	1,577	2,295	1,483	2,424	1,974	4,623	3,916	2,001	854
Edwin	2,897	1,631	3,289	2,562	4,048	2,426	5,314	3,722	3,364	773
Eltan	3,485	1,488	3,067	1,802	3,909	3,294	5,656	4,153	3,176	1,570
Farnum	2,952	1,227	3,268	2,366	3,569	2,836	5,377	3,556	3,827	1,607
Finch	3,801	1,733	4,215	2,424	3,921	2,974	6,138	3,784	3,630	903
Finley	3,438	1,851	2,408	2,093	3,166	2,492	5,276	3,016	2,745	600
Hatton	3,220	1,528	2,629	1,483	3,445	2,587	3,850	3,542	1,621	1,019
Lewjain	3,689	1,419	3,890	2,315	4,289	3,132	5,387	3,630	2,972	847
Madsen	4,131	1,495	2,191	1,641	2,535	2,761	6,272	3,711	3,320	1,459
Masami	3,584	1,239	4,215	2,360	4,164	3,006	6,123	4,033	3,364	1,325
MDM	4,050	1,557	2,399	1,846	3,489	2,645	5,242	4,208	3,035	1,372
Moro	3,655	1,493	2,525	2,668	3,105	2,364	3,749	3,364	2,798	709
Paladin	2,663	1,284	928	2,160	2,265	2,609	4,785	3,911	2,349	1,548
Palomino	2,972	1,443	1,974	2,303	2,347	2,868	4,997	3,840	2,983	1,365
Stephens	3,339	1,821	2,814	1,638	3,038	3,322	5,676	2,951	2,848	879
Tubbs06	3,161	1,342	3,246	2,080	3,309	3,132	6,199	3,670	2,981	960
Xerpha	3,742	1,870	2,698	1,118	4,361	2,392	5,516	3,998	2,972	1,306
	LSD = 746		LSD = 881		LSD = 545		LSD = 639		LSD = 464	

Table 5. Number of site-years that cultivars appeared in the top significance group for grain yield under conventional tilled fallow, late-planted no-till fallow and combined over both systems.

	Grain Yield Summary		
Entry	**Conventional tilled fallow**	**Late-planted no-till fallow**	**Combined**
Bauermeister	1	3	4
Bruehl	3	2	5
Chukar	4	5	9
Eddy	0	1	1
Edwin	2	3	5
Eltan	3	5	8
Farnum	1	3	4
Finch	5	3	8
Finley	1	2	3
Hatton	0	1	1
Lewjain	3	4	7
Madsen	2	3	5
Masami	5	4	9
MDM	1	4	5
Moro	1	2	3
Paladin	0	4	3
Palomino	0	4	4
Stephens	1	2	3
Tubbs06	1	4	5
Xerpha	2	3	5

Five additional cultivars ranked in the top significance group in four of the five years under the late-planted no-till fallow system (Table 5). Unfortunately, these cultivars did not perform well under the tilled fallow system. Tubbs06, Paladin and Palamino performed poorly in the conventional tilled fallow system; however, they ranked in the top significance group in four out of five years in the late-planted no-till system. These three cultivars have shorter than average coleoptiles (data not shown), which often lead to poor emergence and lower yields from the deep planting depths of the tilled fallow system. Due to the shallower planting depth of the late planted no-till system, Tubbs06, Paladin and Palamino were able to achieve better emergence and more competitive yields in that system. Even so, emergence is still an important trait in the late-planted no-till fallow system due to the variability of precipitation that can come in the fall, making these cultivars more of an economic risk than the cultivars that performed well in both the tilled and no-till systems.

The cultivars that ranked in the top significance group the fewest number of times were Eddy and Hatton (Table 5). Eddy and Hatton are both highly susceptible to stripe (yellow) rust (*Puccinia striformis*), which explains a portion of their poor performance. Eddy also showed very poor emergence from the tilled fallow system. The remaining cultivars were in the top significance group less than 50% of the time, indicating they are not well adapted to either system. This could be due to poor emergence, disease susceptibility or other genetic constraints limiting their performance.

Differences in heading date were observed between cultivars and production systems (Table 6). The difference in heading date between the tilled fallow and late planted no-till systems is consistent with other published work [25]. Shah *et al.* [20] demonstrated that the magnitude in yield loss associated with late planting could be lessened by planting earlier maturing cultivars. In our trial, Paladin was among the earliest maturing cultivars in each year and displayed a lower magnitude of yield loss between the two production systems. However, the lower magnitude of yield loss is likely due to the poor performance of Paladin in the tilled fallow system and not a direct result of an earlier heading date, as not all early maturing cultivars in our study behaved in the same manner. Chukar was one of the latest cultivars to reach heading under the late planted no-till system (Table 6). However, it also was in the top significance group for grain yield in the no-till system at all locations. Eltan, another cultivar that performed well in the late planted no-till system, displayed medium maturity.

Correlation analysis was performed on heading date and grain yield data to identify any correlation between the production systems. No significant correlation was found between heading date and grain yield ($R^2 = 0.129$, $p = 0.264$) under the no-till production system. Although the variation in heading data between cultivars ranged from four to nine days, heading date did not significantly impact yield potential. In contrast, a significant correlation was found between heading date and grain yield ($R^2 = 0.44$, $p = 0.001$) under the conventional tilled production system. It was found that lines that had a later heading date also had a higher grain yield potential. In the conventional tilled system, it is advantageous for plants to mature later as they can develop more tillers, produce more biomass and have a long grain fill duration. At these locations, heat stress does not become a limiting factor, so a later heading date is beneficial to grain yield production. In contrast, the no-till production system is delayed in heading date an average of 12 days, as compared to the conventional tilled system. This delay in heading date requires the plants to flower during the hottest part of the year, often inducing some heat stress. Thus, grain yield potential in the no-till system is determined, in part, by other genetic considerations apart from heading date. It appears that in conventional tilled systems in the Pacific Northwest consideration should be placed on later heading dates in order to obtain high grain yield potential. In the later planted no-till systems, heading date does not significantly affect grain yield potential, and consideration should be placed on other traits, such as overall genetic yield potential, heat/drought stress tolerance and disease resistance.

Grain volume weight varied among cultivars. Hatton had grain volume weights in the top significance group in all years and in both planting systems (Table 7). Eddy also ranked in the top significance group for grain volume weight in the late planted no-till system in each year. Interestingly, Hatton and Eddy displayed high grain volume weights, yet their grain yields were among the lowest. While the reasons for Hatton's high grain volume weight may be genetic in nature, it seems more likely that Eddy produced higher grain volume weights as a result of its lower yields. Decreased plant density would lead to lower grain yield, but would also lead to more available soil moisture and, thus, a higher grain volume weight.

Table 6. Heading date (Julian) of winter wheat cultivars grown under conventional tilled fallow and late-planted no-till fallow systems.

	Heading Date							
	Kahlotus 2010		**Lind 2010**		**Ritzville 2011**		**Lind 2011**	
Entry	**Conventional tilled fallow**	**Late-planted no-till fallow**	**Conventional tilled fallow**	**Late-planted no-till fallow**	**Conventional tilled fallow**	**Late-planted no-till fallow**	**Conventional tilled fallow**	**Late-planted no-till fallow**
Bauermeister	142.8	157.0	142.8	159.8	162.5	167.3	159.8	167.5
Bruehl	143.5	158.3	144.3	161.0	161.3	168.5	160.3	167.8
Chukar	143.5	158.3	143.8	160.5	161.0	168.0	158.3	167.8
Eddy	138.3	155.8	138.5	157.0	154.0	160.5	151.0	161.0
Edwin	141.0	156.5	142.3	158.3	156.0	167.3	155.8	166.3
Eltan	143.0	157.8	143.5	159.5	162.0	167.3	160.0	166.5
Farnum	144.8	158.8	145.5	161.3	163.0	168.3	159.3	168.0
Finch	143.3	157.8	143.3	160.3	161.5	168.0	159.3	168.5
Finley	140.8	155.3	140.5	156.0	155.5	164.3	155.8	164.5
Hatton	140.5	155.8	141.8	156.8	155.0	165.5	156.0	165.8
Lewjain	144.5	159.3	144.5	160.3	162.0	168.0	160.3	168.5
Madsen	138.3	156.3	139.8	155.5	158.0	166.0	157.8	166.3
Masami	142.3	157.0	143.0	159.0	161.0	168.3	159.5	167.8
MDM	143.3	157.3	143.0	159.8	161.0	167.3	159.8	167.8
Moro	140.5	156.5	139.8	157.3	157.5	165.5	156.0	165.0
Paladin	139.0	156.3	141.5	155.0	156.0	163.3	154.0	162.0
Palomino	137.3	155.8	138.8	155.3	154.5	160.0	150.5	159.3
Stephens	140.3	155.8	140.3	156.8	155.0	162.3	152.8	162.0
Tubbs06	140.0	156.0	141.3	158.0	155.5	165.5	156.0	165.5
Xerpha	142.8	157.8	142.0	160.5	160.5	166.8	158.0	167.3
	LSD = 1.1		LSD = 1.3		LSD = 1.6		LSD = 1.2	

Table 7. Grain volume weight (kg hL^{-1}) of winter wheat cultivars grown under conventional tilled fallow and late-planted no-till fallow systems.

	Grain Volume Weight							
	Kahlotus 2009		**Kahlotus 2010**		**Lind 2010**		**Ritzville 2011**	
Entry	**Conventional tilled fallow**	**Late-planted no-till fallow**	**Conventional tilled fallow**	**Late-planted no-till fallow**	**Conventional tilled fallow**	**Late-planted no-till fallow**	**Conventional tilled fallow**	**Late-planted no-till fallow**
Bauermeister	76.4	74.0	76.3	74.9	76.8	72.8	77.2	75.5
Bruehl	73.7	72.3	75.5	73.6	76.2	71.0	73.4	73.1
Chukar	73.6	70.3	75.9	73.2	76.8	72.2	74.9	73.2
Eddy	77.7	76.8	79.0	79.5	78.2	77.4	79.0	78.9
Edwin	75.8	75.1	78.7	77.8	79.0	74.8	77.6	76.6
Eltan	75.1	74.1	75.5	74.9	76.5	72.2	75.8	75.7
Farnum	75.6	72.3	74.6	74.4	76.3	70.8	76.4	74.9
Finch	75.6	73.2	77.8	74.5	76.7	71.4	78.1	75.2
Finley	78.3	76.1	78.8	79.1	78.7	76.6	80.5	78.4
Hatton	80.4	76.8	78.7	78.1	79.9	77.8	80.3	80.3
Lewjain	76.0	73.7	75.3	74.4	76.2	71.7	76.7	75.6
Madsen	75.7	72.5	76.8	74.8	75.8	73.5	78.0	74.1
Masami	74.1	72.9	77.0	74.8	77.0	71.5	75.6	73.3
MDM	75.8	74.2	75.9	76.0	76.7	72.5	76.8	76.8
Moro	75.4	73.1	74.3	75.6	77.3	74.1	74.8	74.6
Paladin	77.4	76.6	77.5	79.6	77.4	77.4	78.1	78.8
Palomino	77.4	76.6	76.7	77.8	76.4	76.9	77.6	78.1
Stephens	73.2	71.9	77.8	77.6	77.9	76.1	76.3	73.4
Tubbs06	73.3	72.5	74.1	74.3	76.1	70.6	75.8	72.6
Xerpha	75.1	73.1	74.2	71.2	77.1	71.6	75.9	74.8
	LSD = 1.75		LSD = 2.21		LSD = 1.11		LSD = 1.23	

Cultivar stability across systems, years and locations is one of the most important factors for wheat producers to maintain economic gains. Four cultivars tested had the highest stability, ranking in eight to nine of the highest significant yield groups out of 10 possible. Finch and Masami ranked slightly higher under the tilled fallow system, whereas Chukar and Eltan ranked slightly higher under the no-till fallow system. Even though there was a 35–45% yield reduction moving from the tilled t no-tilled fallow systems in these four cultivars, in contrast to other cultivars that only saw a 20–30% reduction, they were always significantly higher in yield.

4. Summary

Our results indicate that variety selection plays a critical role in producing a competitive wheat crop under a late-planted no-till production system. Those growers in the dryland production areas of the Pacific Northwest who wish to plant winter wheat in a late-planted no-till system may benefit from choosing yield stable cultivars, such as Chukar or Eltan. It was found that in the conventional tilled system, cultivars with a later heading date had significantly higher grain yield potential. In the late-planted no-till system, heading date was not significantly correlated to grain yield, indicating other traits (such as heat/drought tolerance and disease resistance) are important to develop high grain yield potential. Cultivars, such as Chukar and Eltan, which perform well in both systems, have been bred and developed for traits that are beneficial and complimentary to each system, therefore showing their stability across systems, locations and years. For each cultivar tested, yields were lower in the late-planted no-till system compared to the conventional tilled fallow system. While late-planting winter wheat in a no-till production system does not maintain the yield potential of tilled systems, soil erosion and environmental sustainability have prompted growers to switch systems. Many research programs across the country continue to develop production systems that are more environmentally friendly and economically sustainable. Our results indicate that variety selection will also play an important role in the development of those systems. Additionally, plant breeding programs focused on these different systems will need to address the beneficial traits required for both systems to develop varieties with stability across systems, environments and years.

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