Harvesting triticale in Washington. Photo by Matthew Weaver/Capital Press.

FEATURES

Winter Triticale in the Semiarid U.S. Pacific Northwest Drylands

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Triticale is a cereal feed grain grown annually worldwide on 10 million acres. A nine-year dryland cropping systems study was conducted from 2011–2019 near Ritzville, WA to compare winter triticale (WT) with winter wheat (WW) grown in (i) a three-year rotation of WT–SW (spring wheat)–no-till fallow (NTF); (ii) a three-year rotation of WW–SW–undercutter tillage fallow (UTF); and (iii) a two-year WW–UTF rotation. Grain yield, grain yield components, straw production, and effect on the subsequent SW crop (in the two three-year rotations) were measured, and enterprise budgets were constructed to evaluate the production costs and profitability. Earn 1 CEU in Crop Management by reading this article and taking the quiz at www.certifiedcropadviser.org/education/classroom/classes/997. View all CEUs online at https://web.sciencesocieties.org/Learning-Center/Courses.

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The low-precipitation (<14 inch annual) zone of the inland Pacific Northwest (PNW) of the U.S. covers roughly 4.5 million cropland acres in a belt through east-central Washington and north-central Oregon. The Mediterranean-like climate produces wet winters and dry summers. A monocrop two-year rotation of winter wheat–fallow (WW-F) is practiced on >90% of the land. Researchers and farmers have for many decades sought alternative crops and rotations that are equally or more stable and profitable than the WW-F system. A multitude of cereal and broadleaf spring-sown crops so far tested by farmers and researchers in the PNW drylands have not had stable yields nor been economically viable in the long term because of heat and/or water stress encountered during their reproductive period.

In the past 10–15 years, three relatively new winter crops have garnered interest in the region. These crops are winter triticale (WT), winter pea, and winter canola. As with WW, these three new winter crops need to be planted in late August–early September into moisture accumulated in the soil after a 13-month fallow to achieve optimum grain yield potential. Waiting to plant until the onset of fall rains in mid-October or later results in severe yield decline.

Both forage and grain types of triticale are grown. The focus here is grain triticale. Triticale grain is primarily fed to ruminants, pigs, and poultry as it is a good source of protein, amino acids, and B vitamins. Triticale is widely considered to have better tolerance to both saline and low-pH soil conditions compared with wheat. Additionally, triticale is less susceptible to rusts than is wheat, including stripe rust which is a major fungal disease in wheat.

The Experiment

A nine-year dryland cropping systems field experiment was conducted during the 2011–2019 crop years at the Ron Jirava farm near Ritzville, WA to compare the agronomic and economic feasibility of WT compared with WW. Silt-loam soils at the site are >6 ft deep with no rocks or restrictive layers, and slopes are <1%.

The study was part of a large-scale and long-term dryland cropping systems experiment initiated in 1997 to investigate the feasibility of alternative crops and rotations as well as no-till and conservation-till soil management. Both conservation undercutter tillage fallow (UTF) and no-till fallow (NTF) were used during the 13-month fallow period preceding sowing of WW and WT, respectively. In the two three-year rotations, SW was sown directly into the standing and undisturbed stubble of the previous WT or WW crop. Beginning in September 2010, the following rotations were introduced for comparison:

1. three-year WT-SW-NTF
2. three-year WW-SW-UTF
3. two-year WW-UTF

The experimental design was a randomized complete block with four replications. Individual plot size was 30 by 500 ft. All phases of all rotations were present every year (total = 32 plots).

After harvest of all plots in early August, residue was left standing and undisturbed throughout the fall and winter. Undercutter tillage fallow was used in the WW-UTF and WW-SW-UTF rotations in mid-May to mid-June. A Haybuster undercutter with a wide, narrow pitch, overlapping sweep blades on two ranks was used for primary spring tillage plus simultaneous injection of liquid N and S fertilizer. The undercutter sweep blades were operated at approximately a 5-inch depth. The undercutter method is considered a best management conservation practice for primary spring tillage during fallow because it breaks soil capillary continuity to effectively retain soil moisture during the dry summer while leaving most residue on the soil surface and does not pulverize surface clods. One, and sometimes two, rotary rod weeding operations (also noninversion) were conducted at 3-to 4-inch depth during late spring and/or summer to control broadleaf weeds.

No-till fallow was used in the WT-SW-NTF rotation. The soil in these plots had been in no-till with no soil disturbance except for sowing of crops since 1997. Herbicide was applied three to four times from March through August of the fallow year. As WT was sown into NTF, liquid N and S fertilizer was stream-jetted onto established WT seedlings in late October or early November just prior to an expected substantial rain. Fertility requirements for WT and WW are similar; thus, N and S fertilizer application rates for these two crops were held constant every year with a starter fertilizer of P, Zn, and B applied in the seed row with the deep-furrow drill at sowing.

Sowing

Winter triticale and WW were sown on the same day every year within the first 10 days of September with a custom-built deep-furrow drill with 17-inch row spacing. Sowing rate for WT and WW were held constant at 50 lb/ac with 3 to 5 inches of soil covering seed (Figure 1). All seed was treated with a broad-spectrum fungicide and an insecticide for wireworm control. Successful stand establishment of WT and WW was achieved every year (Figure 2).

Washington State University and USDA are equal opportunity providers and employers. Abbreviations used in the article include: NTF, no-till summer fallow; PNW, inland Pacific Northwest; SW, spring wheat; UTF, undercutter minimum tillage summer fallow; WSU, Washington State University; WT, winter triticale; and WW, winter wheat.

Spring wheat was sown directly into the standing residue of the previous WT or WW crops as soon as soil conditions allowed on dates ranging from March 15 to April 7. Sowing rate was 70 lb/ac. Fertilizer was deep-banded at the time of sowing at an average of 42, 6, and 6 lb/ac of N, P, and S, respectively. Fertilizer rates varied each year depending on soil test results and expected SW yield potential based on residual fertilizer and available soil water. The fertilizer rates for SW following both WT and WW were always the same.

Figure 1. Winter triticale and winter wheat were planted with a deep-furrow drill on 17-inch row spacings. Surface drying occurs from fallowed soils during the dry summer months, and seed must be planted deep to reach soil moisture that was stored during the winter. The deep furrows reduce the depth of soil covering the seed, yet seedlings must emerge through 3 to 5 inches of soil to reach the surface.

In-Crop Weed and Stripe Rust Control

Several in-crop herbicide formulations were applied at labeled rates over the nine years to control broadleaf weeds in WT, WW, and SW. Some of these herbicides have different modes of action, which is required to slow/reduce the development of herbicide-resistant weeds. For WW, the fungicide propiconazole for control of stripe rust was tank-mixed with the broadleaf herbicide in all but two years. Fungicide was not required for WT as no stripe rust lesions were observed in any year. Fungicide was also not applied to SW as the warmer, drier weather conditions during its active growth was not conducive to stripe rust infection.

Figure 2. Winter triticale (WT) grown in individual 30 by 500 ft (0.33 acre) plots at the long-term cropping systems experiment near Ritzville, WA. Grain yield of WT shown here was 82 bu/ac. Over nine years, grain yield of WT ranged from 63 to 111 bu/ac and averaged 86 bu/ac (expressed in 60-lb bushels).

Grain Yield, Yield Components, and Straw Dry Biomass

Winter triticale, WW, and SW were harvested every year in early August. A commercial-size combine with 25-ft-wide header was used to harvest the entire 500-ft length of each plot with the grain augured into a weigh wagon.

For WT and WW in both two- and three-year rotations, spike density was measured by counting the number of grain-bearing spikes from a randomly selected 1-m row section in each plot just prior to grain harvest and hand-clipped, collected, and processed using well-established standard procedures. Straw dry biomass was determined by subtracting the weight of the grain from the whole aboveground plant weight.

Economic Assessment

Enterprise budgets were constructed for each rotation with annual costs based on actual inputs and field operations used each year and with annual income based on measured yields. Fertilizer, seed, and pesticide input costs were based on 2019 prices from local suppliers. Machinery costs were estimated for farm-scale equipment and included repairs, labor, fuel and lube, depreciation, and overhead costs. To focus the economic analysis on crop production impacts, crop prices were fixed at the eight-year (2012–2019) average of local market prices on September 1 of each year. Rotation-average costs and returns were calculated as the average of costs and returns for each phase of the rotation. The standard deviation of rotation-average annual net returns across years was included as a measure of economic risk.

Results

Crop-Year Precipitation

Crop-year (Sept. 1–Aug. 31) precipitation ranged from 10.1 to 17.3 inches and averaged 12.9 inches over the nine years. The 2014 and 2015 crop years were the only periods with considerably below-average precipitation. Much greater than average precipitation fell in the 2016 and 2017 crop years.

TABLE 1. Straw dry biomass, stem number, and stem weight for winter triticale and three- and two-year winter wheat averaged over five years (2015–2019) at Ritzville, WA.

	Straw dry biomass (lb/ac)	Stem number	Stem weight
	lb/ac	no./m^2	g/stem
Winter triticale (3-yr)	6,495 ab[a]	284 c	2.36 a
Winter wheat (3-yr)	6,710 a	486 a	1.47 b
Winter wheat (2-yr)	5,795 b	398 b	1.51 b
p-value	.010	< .001	< .001
HSD (0.05)[b]	720	50	0.16

[a]Within-column letters followed by a different letter are significantly different.
[b]HSD = honest significant difference.

Straw Weight and Stem Number of Winter Triticale vs. Winter Wheat

There were no statistical differences in the weight of dry WT straw/m^2 compared with three- and two-year WW. The three-year WW, however, produced a much greater quantity of dry straw than did two-year WW (Table 1). There were huge differences between WT and WW in the number of stems per square meter and individual stem weight (Table 1). Winter triticale produced an average of only 284 stems/m^2 compared with 486 and 398 stems/m^2 for three- and two-year WW, respectively. Stems of WT were much thicker and heavier than those of WW with an individual stem weight of 2.36 g for WT compared with 1.47 g for three-year WW and 1.51 g for two-year WW (Figure 3, Table 1). There were never any within-year differences in individual stem weight between three- and two-year WW, but three-year WW always produced significantly more stems per square meter than two-year WW and in the long-term average as summarized in Table 1.

Figure 3. Winter wheat (WW, left) and winter triticale (WT, right) ripe for harvest at the long-term cropping systems experiment near Ritzville, WA. Averaged over nine years, WT produced significantly more grain than WW. The higher grain yield achieved by WT was due to greater number of kernels per spike and heavier kernel weight despite having much fewer spikes per square meter compared with the WW.

TABLE 2. **Grain yield of winter triticale (WT) and three- and two-year winter wheat (WW) for nine years and averaged over years at Ritzville, WA. Both WT and WW yields are expressed as 60 lb bushels.**

	2011	2012	2013	2014	2015	2016	2017	2018	2019	Avg.
	Grain yield (bu/ac)									
WT (3-yr)	104 a[a]	75	82 a	65	63 a	111 a	92 a	99 a	87 a	86 a
WW (3-yr)	73 b	79	81 a	55	56 ab	94 b	82 b	88 b	74 b	75 b
WW (2-yr)	75 b	75	63 b	55	47 b	94 b	78 b	74 c	69 b	69 c
p-value	.007	ns[†]	< .001	ns	.012	.020	< .001	< .001	< .001	< .001
HSD (0.05)[b]	21	9	9	17	11	15	6	9	8	4

[a]Within-year letters followed by a different letter are significantly different.
[b]HSD = honest significant difference.
[†]ns = non-significant.

Grain Yield of Winter Triticale and Winter Wheat

Over the nine years, WT produced 14 and 24% greater grain yield than three- and two-year WW, respectively. Winter triticale grain yield ranged from 63 to 111 bu/ac and averaged 86 bu/ac (Table 3). Grain yield averaged 75 bu/ac for three-year WW and 69 bu/ac for two-year WW. Importantly, here we express both WT and WW grain as 60 lb/bu. Winter triticale grain yield was significantly greater than either WW system in most years, and the nine-year average grain yield differences were highly significant with WT > three-year WW > two-year WW (p<.001, Table 3). The relative differences in grain yield among the three treatments did not change in dry or wet crop years.

Winter triticale produced an average of 46 kernels/spike vs. 34 kernels/spike for both three- and two-year WW (data not shown). The average 1,000-kernel weight was 44, 31, and 33 g for WT, three-year WW, and two-year WW, respectively. Thus, the higher grain yield achieved by WT was due to a greater number of kernels per spike and heavier kernel weight despite having much fewer spikes per square meter compared with the WW treatments (Figure 3).

Grain Yield of Spring Wheat

Spring wheat grain yield among years was highly variable and ranged from 21 to 51 bu/ac (data not shown). There were no treatment differences in SW grain yield after WT versus WW in any year, but averaged over the years, yield of SW after WT was slightly but significantly greater than SW after WW (p = .022, data not shown). Average grain yield of SW was considerably less than half of that of WT and WW.

Economic Analysis

Production costs for the WT phase were not significantly different from the WW phases of the rotations. Costs for NTF were $13/ac higher than for UTF. This was due to higher costs for herbicide applications to control weeds in NTF compared with use of the rod weeder implement in UTF. The total cost for the SW phase was the same for the three-year rotations. Rotation average costs for the three-year rotations were both higher than for the two-year rotation due to the higher cost of the

TABLE 3. **Rotation average annual net returns and average standard deviation over years (2012–2019) based on average crop prices.**

Rotation[a]	2012	2013	2014	2015	2016	2017	2018	2019	Avg.	SD
	Net returns ($/ac)									
WT-SW-NTF	58 b[b]	93 b	36 b	36	141	89 c	115	78 b	81 b	37
WW-SW-UTF	88 a	109 a	43 ab	51	157	105 b	130	87 b	96 a	38
WW-UTF	110 a	87 b	64 a	51	162	125 a	113	102 a	102 a	35
p-value	.001	.010	.048	ns[†]	ns	< .001	ns	.003	.006	
HSD (0.05)[c]	23	15	27	21	35	10	22	13	15	

[a]WT = winter triticale; WW = winter wheat; SW = spring wheat; NTF = no-till fallow; and UTF = undercutter tillage fallow.
[b]Different letters within each year indicate significant difference in net returns (p < .05).
[c]HSD = honest significant difference.
[†]ns = non-significant.

SW phase of the three-year rotations compared with the other rotation phases.

Average net returns for WW-UTF were numerically, but not significantly, higher than for WW-SW-UTF (Table 3), and both were significantly more profitable (p = .006) than WT-SW-NTF (Table 3). Inter-annual variation in net returns was higher for the three-year rotations than for WW-UTF. If the same WT yields had been obtained using UTF instead of NTF, the cost reduction for UTF relative to NTF would have increased average net returns for the WT rotation by $4/ac to $85/ac. This is still significantly lower than the net returns for WW-UTF but not significantly lower than for WW-SW-UTF. If the same WT yields had been obtained using UTF instead of NTF in the WT rotation, triticale prices or yields would need to be 16 and 11% higher for the WT rotation to be as profitable as the WW-UTF and WW-SW-UTF rotations, respectively.

Discussion

Triticale is widely reported to consistently produce higher grain yields compared with wheat. This held true in our study where yield differences between WT and three-year WW were highly statistically different. In addition, three-year WW achieved significantly greater average yield than two-year WW.

There are many statements in the literature that WT produces more dry straw biomass than WW, but these have been largely based on visual observations and rarely quantified. In our study, the thick WT stems that weighed 60% more than those of WW visually masked the fact that WT had far fewer stems. We consistently found no differences in the quantity of straw produced between WT and WW. This information is important because farmers in low-precipitation Mediterranean environments want and need to produce as much straw as possible.

Winter triticale grew much more rapidly than WW in late winter–early spring, flowered earlier than WW, and was ripe for harvest at least seven days earlier than WW. Below-freezing nighttime air temperatures occurred some years during flowering of WT, but frost damage was rarely observed; whereas, it is well understood that substantial plant injury and subsequent grain yield decline occurs with frosts during flowering of WW.

Some PNW dryland farmers have expressed reluctance to plant WT because its male parent is cereal rye whose seed can lay dormant in/on the soil for several years. Such “feral” cereal rye and WT are somewhat similar in appearance, and both grow ≥ 4 inches taller than semi-dwarf WW; therefore, volunteer plants are easily seen in a WW field. However, importantly, unlike cereal rye, triticale seed has little to no primary dormancy, and like wheat, does not persist in the seed bank. Thus, the concern of some farmers that WT will become a feral weed is unfounded.

The early maturity of WT is favorably viewed by dryland farmers in east-central Washington as it allows for its harvest before WW. Farms are large and many farmers own or rent two or three combines. As the region is almost exclusively in two-year WW-F, including WT on some farmland acres would spread the optimum period for grain harvest over a longer time window, which would likely allow some farmers to reduce the number of combines needed.

Although WT produced an average of 14 and 24% greater grain yield than three- and two-year WW, respectively, it was not economically competitive with either WW system, primarily since it fetched a considerably lower market price. Equal profitability could be attained by 11–16% higher WT price or 11–16% higher WT yield or a combination of price and yield increases.

The SW phase of the three-year rotations is not as profitable as the WT or WW phase of these rotations. While the cost of SW production is similar to that of WW, the annualized cost for WW, including the cost of fallow, is lower than the cost of SW production while the annualized yield for WW is higher than for SW. However, the lack of profitability for SW is partially offset by the rotational yield benefits to the WW phase of the WW-SW-UTF rotation. As a result, net returns for WW-UTF were not significantly different from net returns for WW-SW-UTF.

Conclusion

Winter triticale is an easy-to-grow and hardy crop that produced significantly greater grain yield than WW. Spring wheat grain yield was slightly, but significantly, greater after WT versus after WW. Unlike essentially all reports to the contrary, WT did not produce greater dry straw biomass than WW. The WT rotation was less profitable than the WW rotations due to the lower price of WT. Additional yield improvements or development of higher-value uses for WT that increase the price of WT relative to wheat would help WT be economically competitive with WW rotations. This may be feasible in future years due, for example, to recent promising research with selected 1R chromosomes and known wheat alleles to improve protein, hardness, and gluten strength of triticale grain for bread making.

DIG DEEPER

A full write-up of the study is available: Schillinger, W.F., & Archer, D.W. (2020). Winter triticale: A long-term cropping systems experiment in a dry Mediterranean climate. *Agronomy BASEL, 10*,1777. https://doi.org/10.3390/agronomy10111777

SELF-STUDY CEU QUIZ

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1. Greater than 90% of the land in the low-precipitation zone of the Pacific Northwest practices this rotation:

a. Winter wheat–spring wheat–undercutter tillage fallow.

b. Winter wheat–fallow.

c. Three-year winter triticale–spring wheat–no-till fallow.

d. Continuous annual spring wheat.

2. Which of the following is NOT a winter crop gaining interest in the low-precipitation zone of the PNW?

a. Winter pea.

b. Winter canola.

c. Winter triticale.

d. None of the above.

3. Compared to wheat, triticale is ________ susceptible to rusts and has ________ tolerance to saline and low pH soil conditions.

a. more, better

b. less, better

c. more, worse

d. less, worse

4. When was the undercutter tillage implement used during fallow in the two- and three-year winter wheat rotations?

a. Mid-January to mid-March.

b. Mid-March to mid-May.

c. Mid-May to mid-June.

d. Mid-July to mid-October.

5. Sowing rate for winter triticale was ________ lb/ac and ________ lb/ac for spring wheat.

a. 20, 40

b. 50, 70

c. 70, 50

d. 40, 20

6. Which crop produced the most individual stems per square meter?

a. Two-year winter wheat.

b. Three-year winter wheat.

c. Winter triticale.

d. None of the above.

7. Winter triticale produced ________% and ________% greater grain yield than two- and three-year winter wheat, respectively.

a. 14, 24

b. 44, 31

c. 24, 14

d. 31, 44

8. How did winter triticale achieve higher grain yield than winter wheat?

a. Greater number of spikes per square meter.

b. Fewer kernels per spike but heavier kernel weight.

c. Lighter kernel weight but more kernels per spike.

d. None of the above.

9. Three-year winter wheat achieved significantly greater average yield than two-year winter wheat.

a. True.

b. False.

10. Thick winter triticale stems weighed ________% more than those of winter wheat.

a. 30

b. 40

c. 50

d. 60