

Project Title: Impact of Crop Rotation and Alternative Crops on Weed Populations, Yield, and Economic Performance in Direct Seed System in the Intermediate Rainfall Area of Washington.

Investigator: Aaron Esser, WSU Extension Agronomist, Lincoln-Adams Area.

Interim Report

Objectives: The objectives of this project are to evaluate the impact of various direct seeded crop rotations that include winter wheat, chemical fallow, spring grains and broadleaf crops on yields, weed populations, soil moisture, and overall profitability.

Key Words: alternative crops, crop rotations, direct seeding, chemical fallow

Statement of Problem: Growers in the intermediate rainfall area of Washington have struggled to make direct seeded continuous cropping systems work both agronomically and economically during the abnormally dry summer conditions experienced during the past few years. Because of these struggles, grower's interest in chemical based summer fallow systems and incorporating winter wheat into crop rotations has increased. Lack of information about the effect of alternative crops on cereal grain production has also limited the effectiveness of designing profitable direct seeded crop rotations in the intermediate rainfall area of Washington.

Zone of interest: Intermediate rainfall zone

Abstract of Research Findings: This study was initiated in 2004 and is being conducted at the WSU Wilke Research and Extension Farm near Davenport, WA to evaluate the impact of various direct seeded crop rotations that include winter wheat, chemical fallow, spring grains and broadleaf crops on yields, weed populations, soil moisture, and overall profitability. The study is a randomized complete block design with 4 replications. Over the past 3 years winter wheat yields and weed pressure remains variable ranging from 54.8 bu/ac to only 33.7 bu/ac and weed pressure ranging from 5.9 to as low as 4.0. Infestations of common rye (*Secale cereal L.*), although it has been reduced, continue to limit winter wheat production especially following chemical fallow, spring cereal rotations. Overall, however winter wheat in rotation following chemical fallow remains greater than following recrop situations. Little differences in weed pressure and yield were detected in all spring cereals regardless of rotations. Spring wheat has averaged 36.2 bu/ac, barley has averaged 1.34 ton/ac, spring grain has averaged 35.3 bu/ac and the broadleaf (yellow and oriental) mustard has averaged 558 lb/ac, respectfully. Chemical fallow plots have been maintained mostly weed free with multiple applications of glyphosate and 2, 4-D each year. Variable costs have increased nearly 77% from 2006 to 2008, and rotation 1; continuous spring barley, and rotation 6; spring grain, broadleaf, winter wheat, despite higher costs has a greater economic return over variable costs than rotation 3; chemical fallow, winter wheat.

Results and Interpretation: Background and Methods: The focus of this project is to evaluate the impact of various direct seeded crop rotations that include winter wheat, chemical fallow, spring grains and broadleaf crops on yields, weed populations, soil moisture, soil quality, and overall profitability. Results from the four year Wilke project concluded that cereal production in

a rotation was generally the only crop that was profitable, therefore, maximizing cereal yield (especially winter wheat) in a rotation is desirable. This experiment was initiated in the spring of 2004, and is being conducted at the WSU Wilke Research and Extension Farm near Davenport, WA in an area with historically 15 inches of precipitation per year. To date all nine rotations have been through a complete sequence. The nine crop rotations are as follows:

Rotation #, Crop Sequence	Years of Rotation	% Rotation in WW
1 sb	1	0
2 sw	1	0
3 sf/ww	2	50
4 sw/cf/ww	3	33
5 sb/cf/ww	3	33
6 sg/bl/ww	3	33
7 sw/sb/bl/ww	4	25
8 sg/bl/cf/ww	4	25
9 sg/sg/cf/ww/ww	5	40

Abbreviations: sb, ‘Baroness’ spring barley each year; sw, ‘Alpowa’ common soft white spring wheat in 2006, and ‘Louise’ in 2007 and 2008; ww, ‘Chukar’ soft white winter club wheat in 2006 and 2007, and ‘ORCF 102’ in 2008; cf, chemical based fallow; sg, ‘Tara 2002’ Dark Northern Spring wheat each year; bl, ‘IdaGold’ yellow mustard in 2006 and 2007, and ‘Pacific Gold’ oriental mustard in 2008.

The study is a randomized complete block design with 4 replications. Prior to initiating the study, the site location had been direct seeded for five years with replications I and II being on ground in a 3-year crop rotation that concluded with yellow mustard and replications III and IV being on ground also in a 3-year crop rotation but concluded with recrop winter wheat. Plots are 48 by 12 feet in size. All crops are fertilized at time of seeding based on soil tests and projected crop yield. The study is seeded with a Fabro™ double disk direct seed plot drill with a leading coulter for nitrogen fertilizer placement. Starter fertilizer is applied with the seed.

Soil Moisture and Precipitation: Soil moisture data is being collected prior to seeding crops both in the spring and fall of the year to determine yield potentials for nitrogen fertilization as well as water use efficiency of each rotation. Data collected will be analyzed and presented in following reports.

Herbicide Application and Chemical Fallow Management: Weed pressure was assessed during mid July scoring each plot 0-10 with 10 being weed free and 0 being a very heavy infection that were previously removed with a mower and treated with glyphosate. Overall the study location is characterized as having a heavy infestation of common rye (*Secale cereal L.*), a population of wild oat (*Avena fatua L.*), and downy brome (*Bromus tectorum L.*).

In 2006 winter wheat in all but rotation 5 was treated with Olympus Flex™ at 3 oz/ac to control downy brome. Winter wheat in rotation 5 was not treated for cheat grass because of herbicide plant back restrictions. All winter wheat in rotation was treated with 2,4-D at a rate of 16 oz/ac to control broadleaf weeds. In 2007 winter wheat in all plots was treated with Osprey™ at 4.75 oz/ac to control downy brome, and MCPA at a rate of 16 oz/ac to control broadleaf weeds.

Recrop winter wheat was not seeded because of a lack of soil moisture and very little weed and

volunteer crop germination. Spring wheat was seeded instead in 2007. In 2008 winter wheat following chemical fallow in rotations 3 and 9 was treated with Beyond at 4 oz/ac on October 23, 2007 and May 6, 2008 for annual grassy weeds. Brox-M was tank mixed in May at 24 oz/ac to control broadleaf weeds. Winter wheat in all other plots were treated with Osprey™ at 4.75 oz/ac to control downy brome, and Brox-M at a rate of 24 oz/ac to control broadleaf weeds. Recrop winter wheat in rotations following mustard (#6 & #7) was seeded, and recrop winter wheat following winter wheat (#7) was held over and seeded to spring wheat to better control common rye.

In 2006, 2007, and 2008 glyphosate was applied at 21, 28 and 16 oz/ac prior to seeding spring planted crops. Fall glyphosate was applied at 8 oz/ac in 2007 for 2008 spring crops. In 2006 and 2007 all spring wheat and spring grain plots were sprayed with 10 oz/ac Discover™ for wild oat control and 16 oz/ac of 2,4-D for broadleaf control. Spring barley plots were sprayed with a tank mix of 10.6 oz/ac Puma™ and 12 oz/ac MCPA for wild oat and broadleaf weed control. Mustard plots were sprayed 8 oz/ac Assure II™ for wild oat control. In 2008 spring wheat and barley were sprayed with a tank mix of 16.4 oz/ac Axial XL™ and 11 oz/ac Huskie™ for wild oat and broadleaf weed control. Mustard was sprayed with 5 oz/ac Select™ for wild oat control.

Chemical fallow plots were maintained mostly weed free each year. All glyphosate applications were tank mixed with 1 qt nonionic surfactant and 15 lbs ammonium sulfate per 100 gal water and applied at 12-gal/ac. In 2006 glyphosate was applied on April 10, and June 24 at 21 oz/ac. Glyphosate was applied at 24 oz/ac and tank mixed with 16 oz/ac 2,4-D on August 21, 2006. In 2007 glyphosate was applied on April 11, at 28 oz/ac. Glyphosate was applied at 24 oz/ac and tank mixed with 16 oz/ac 2,4-D on June 14 and July 31, 2007. In the fall of 2007 glyphosate was applied at 8 oz/ac for 2008 chemical fallow. In 2008 glyphosate was applied on May 5 at 16 oz/ac. Glyphosate was applied at 24 oz/ac and tank mixed with 16 oz/ac 2,4-D on June 16 and August 11, 2008.

Stand Establishment, Weed Pressure and Grain Yields:

Crop establishment was assessed and overall plant populations each year were typical for the region including good stand establishment on winter wheat seeded into chemical fallow (data not presented). Weed pressure was analyzed over all 26-crop treatments, and yield was analyzed for each crop type.

Winter wheat was the most variable crop in both weed control and yield over the last 3 years. In 2006, six winter wheat plots were removed and no yield was recorded because of severe rye infestations, in 2007 only three plots were removed but recrop winter wheat plots were held and seeded to spring wheat. In 2008 three plots were removed and recrop winter wheat following winter wheat was not seeded to winter wheat and held over and seeded to spring wheat. No significant differences were detected in weed pressure between winter wheat in each of the 7 rotations with an average score of 4.1 (Table 1). Over the 3-years winter wheat averages have not been significantly different within the 7 rotations with an average yield of 44-bu/ac. A significant rotation x year interaction in yield was detected and was mostly caused because of common rye management that includes plot removal and failing to plant recrop winter wheat because of dry conditions that don't allow for weed germination prior to fall planting and has led to planting spring wheat.

Averaged over the 3 years, no differences were detected in spring wheat within rotations in weed pressure and grain yield. Weed pressure averaged 6.8 with broadleaf weeds and wild oat populations were noted each year (Table 2). Grain yield averaged 36.2 bu/ac. Similar to spring wheat, no differences in grain yield and weed pressure were detected in spring barley with a 3-year average yield of 1.34 tons/ac and weed pressure average of 7.7 (Table 3). Wild oat and broadleaf weed pressure was noted in each of the three years.

Spring grain plots were Dark Northern Spring wheat in each of the three years. Similar to the spring wheat plots, no differences in weed pressure or grain yield were detected among the spring grain treatments in rotation with an average weed pressure score of 7.9 and grain yield of 35.3 bu/ac (Table 4). Similar to other spring cereals, broadleaf weed pressure and wild oat populations were noted throughout the plots. Averaged over the 3 years, no differences were detected in mustard within rotations in weed pressure and seed yield. Weed pressure averaged 7.5 with broadleaf weeds and wild oat populations noted each year (Table 5). Yellow mustard over the 3 years has averaged 558 lb/ac with yield being limited by weed pressure and frost in (2006), and flea beetle damage (2007).

Economic Performance:

Cereal grain gross economic returns were determined using the F.O.B. price at Ritzville Warehouse on September 15 each year. Test weight and protein discounts and premiums were applied where applicable. Gross economic returns of mustard were generated using the average contract price for the region each year (personal communication). Variable costs include seed, fertilizer and herbicides and have been established through surveying multiple farm chemical supply companies in Lincoln County. Additional costs, including equipment and overhead, were not included as they are assumed to be equal over rotations.

Table 6 summarizes average gross economic return of each rotation, and Table 7 summarizes average variable costs for each rotation. Overall input costs has increased nearly 77% over the 3 year period with rotation 3 having the greatest increase at 106% and rotation 5 having the smallest increase at 51%. Similar to previous reports, spring barley produced higher gross return, had the highest average cost per acre, but produced the highest economic return over costs at \$180/ac, significantly greater than rotation 3 at only \$61/ac (Table 8). Rotation 6 had an average return over costs of \$156/ac which was also greater than rotation 3. A significant rotation x year interaction was detected meaning rotations varied within years. This can partially be explained in replacing recrop winter wheat in rotations 6, 7, and 9 with spring wheat in 2007 and variations in spring barley.

Impact of Research: To date the impact of this research continues to be limited but as more data is collected outreach will be increased. As this study progresses continuous barley remains more profitable than winter wheat-chemical fallow under heavy rye infestations but improved management in the future may change these results. At the conclusion of this study, producers throughout the intermediate cropping area will have a better understanding of profitable direct seeded crop rotations and incorporating winter wheat and chemical fallow into direct seed crop rotations.

Interaction With Other Scientists Conducting Related Activities: This project is complimentary to other cropping systems projects funded by STEEP. Chemical fallow plots, in the absence of high Russian thistle (*Salsola iberica* Sennen) populations, are managed in relationship to Joe Yenish et.al STEEP funded project work examining herbicide efficacy in chemical fallow management. Additional interactions include Bill Schillinger, Rich Koenig, Don Wysocki, and Dennis Roe.

Publications and Presentations:

Data from this project was presented at the 2008 Northern Lincoln County Field Day. A presentation at the Washington State Weed Association Conference in 2008 entitled ‘*Weed Control in Oil Seed Crops*’ highlighted specific results of this study focused on weed control options.

Table1. Average weed pressure and grain yield within the winter wheat plots following either chemical fallow or recrop in various crop rotations at the WSU Wilke Farm near Davenport, WA in 2006-08.

Rotation #, crop sequence	Weed Pressure (score 1-10) ^a	Grain Yield (bu/ac)			Mean
		Year			
		2006	2007	2008	
#8 sg/bl/cf/ww	5.8	74.5	32.0	58.0	54.8
#9 sg/sg/cf/ww/ww	4.0	46.3	56.2	52.9	51.8
#5 sb/cf/ww	5.9	66.4	53.2	34.1	51.2
#4 sw/cf/ww	4.8	42.2	58.8	43.5	48.2
#6 sg/bl/ww	5.9	36.1	42.8	42.0	40.3
#3 cf/ww	4.8	48.5	20.9	44.6	38.0
#9 sg/sg/cf/ww/ww	5.2	15.4	42.4	44.3	34.0
#7 sw/sb/bl/ww	5.4	37.5	33.8	29.8	33.7
Mean	4.1	45.9	42.5	43.6	44.0
LSD (0.05)	n.s.	Sig. rotation x year interaction, = 27			

^a Weed pressure was assessed visually on a score of 0-10 with 0 being very heavy infestations that required removing and 10 being free of weeds.

Table 2. Average weed pressure and grain yield within the spring wheat plots in various crop rotations at the WSU Wilke Farm near Davenport, WA in 2006-08.

Rotation #, crop sequence	Weed Pressure (score 1-10) ^a	Grain Yield (bu/ac)			Mean
		Year			
		2006	2007	2008	
#4 sw /cf/ww	6.8	31.4	45.8	40.3	39.2
#7 sw /sb/bl/ww	6.8	34.6	42.4	37.1	38.0
#2 cont. sw	6.7	27.7	30.7	35.8	31.4
LSD (0.05)	n.s.				n.s.

^a Weed pressure was assessed visually on a score of 0-10 with 0 being very heavy infestations that required removing and 10 being free of weeds.

Table 3. Average weed pressure and grain yield within the spring barley plots in various crop rotations at the WSU Wilke Farm near Davenport, WA in 2006-08.

Rotation #, crop sequence	Weed Pressure (score 1-10) ^a	Grain Yield (ton/ac)			Mean
		Year			
		2006	2007	2008	
#5 sb /cf/ww	7.7	1.28	1.57	1.40	1.42
#1 cont. sb	7.9	0.99	1.66	1.46	1.37
#7 sw /sb/bl/ww	7.5	0.93	1.42	1.38	1.24
LSD (0.05)	n.s.				n.s.

^a Weed pressure was assessed visually on a score of 0-10 with 0 being very heavy infestations that required removing and 10 being free of weeds.

Table 4. Average weed pressure and grain yield within the spring grain plots in various crop rotations at the WSU Wilke Farm near Davenport, WA in 2006-08.

Rotation #, crop sequence	Weed Pressure (score 1-10) ^a	Grain Yield (bu/ac)			Mean
		Year			
		2006	2007	2008	
#9 sg /sg/cf/ww/ww	7.6	37.1	49.9	29.5	38.8
#6 sg /bl/ww	8.0	34.9	51.2	25.8	37.3
#9 sg /sg/cf/ww/ww	9.0	30.2	45.4	24.5	33.4
#8 sg /bl/cf/ww	6.8	23.8	37.2	34.2	31.7
LSD (0.05)	n.s.				n.s.

^a Weed pressure was assessed visually on a score of 0-10 with 0 being very heavy infestations that required removing and 10 being free of weeds.

Table 5. Average weed pressure and grain yield within the broadleaf plots seeded to yellow or oriental mustard in various crop rotations at the WSU Wilke Farm near Davenport, WA in 2006-08.

Rotation #, crop sequence	Weed Pressure (score 1-10) ^a	Grain Yield (lb/ac)			Mean
		Year			
		2006	2007	2008	
#8 sg/bl/cf/ww	7.6	298	765	735	599
#6 sg/bl/ww	7.4	323	600	692	538
#7 sw/sb/bl/ww	7.4	373	645	595	538
LSD _(0.05)	n.s.				n.s.

^a Weed pressure was assessed visually on a score of 0-10 with 0 being very heavy infestations that required removing and 10 being free of weeds.

Table 6. Average gross economic return of nine direct seeded crop rotations at the WSU Wilke Farm near Davenport, WA in 2006-08.

Rotation #, crop sequence	Gross Economic Return ^a			Mean
	Year			
	2006	2007	2008	
	----- \$/ac -----			
#1 cont. sb	100	401	262	254
#6 sg/bl/ww	121	296	258	225
#7 sw/sb/bl/ww	108	275	227	203
#2 cont. sw	104	250	234	196
#9 sg/sg/cf/ww/ww	116	259	194	190
#4 sw/cf/ww	98	285	183	189
#5 sb/cf/ww	136	272	158	189
#8 sg/bl/cf/ww	117	180	241	179
#3 cf/ww	101	85	146	111
Mean	111	256	211	193
Sig. rotation x year interaction, LSD _(0.05) = 75				

^a F.O.B. price on Sept. 15 each year at Ritzville Warehouse for cereals and yearly mustard contract prices were used to calculate gross economic return. Grain protein and test weight premium and discounts were applied when applicable.

Table 7. Average variable costs including seed, fertilizer and herbicide of nine direct seeded crop rotations at the WSU Wilke Farm near Davenport, WA in 2006-08.

Rotation #, crop sequence	Variable costs ^a			Mean
	Year			
	2006	2007	2008	
	----- \$/ac -----			
#2 cont. sw	55	67	100	74
#1 cont. sb	57	69	95	74
#6 sg/bl/ww	54	68	86	69
#7 sw/sb/bl/ww	53	66	86	68
#9 sg/sg/cf/ww/ww	48	61	91	67
#8 sg/bl/cf/ww	45	57	76	59
#4 sw/cf/ww	41	52	70	54
#5 sb/cf/ww	37	53	69	53
#3 cf/ww	34	46	70	50
Mean	47	59	83	63

Sig. rotation x year interaction, $LSD_{(0.05)} = 1$

^a Variable costs include, seed, fertilizer and herbicides. They were established through surveying multiple suppliers in Lincoln County.

Table 8. Return over variable cost of nine direct seeded crop rotations at the WSU Wilke Farm near Davenport, WA in 2006-08.

Rotation #, crop sequence	Economic Return over Variable Costs			Mean
	Year			
	2006	2007	2008	
	----- \$/ac -----			
#1 cont. sb	43	331	167	180
#6 sg/bl/ww	68	228	171	156
#5 sb/cf/ww	98	219	90	136
#7 sw/sb/bl/ww	55	208	141	135
#4 sw/cf/ww	57	233	113	134
#9 sg/sg/cf/ww/ww	68	198	103	123
#2 cont. sw	49	183	134	122
#8 sg/bl/cf/ww	72	124	165	120
#3 cf/ww	67	39	76	61
Mean	64	196	129	130

Sig. rotation x year interaction, $LSD_{(0.05)} = 75$