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.

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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, soil quality, 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 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, disease, soil moisture and quality, 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 60.6 bu/ac to only 23.8 bu/ac and weed pressure ranging from 5.1 to as low as 3.2. Heavy infestations of common rye (*Secale cereal* L.) continue to limit production especially in rotation 3, winter wheat-chemical fallow. Overall, however winter wheat in rotation following chemical fallow remains greater than following recrop situations. Little differences in weed pressure and yield was detected in spring wheat in varied rotations with an average weed pressure score of 6.8 and 34 bu/ac yield. Spring barley in combination with a rotation including chemical fallow had less weeds than continuous systems but no differences were detected in yield with an average of 1.38 ton/ac. Spring grains following recrop winter wheat had greater yield than spring grain in rotation following winter wheat and chemical fallow. No differences were detected in weed pressure or yield of yellow mustard in varied rotations with an average weed score of 6.53 and a yield of 515 lb/ac. Chemical fallow plots have been maintained mostly weed free with 3 applications of glyphosate each year. Overall rotation 1, continuous spring barley, has the highest average gross return, variable costs per acre, and highest average return over costs per acre at $147/ac, significantly greater than other continuous crop rotations and winter wheat, chemical fallow 2-year rotation.

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 8 of the 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 2005 and 2006, 'Louise'in 2007; **ww,** 'Chukar' soft white winter club wheat; **cf,** chemical based fallow; **sg,** 'Alpowa' common soft white spring wheat in 2005 and 'Tara 2002' Dark Northern Spring wheat in 2006 and 2007; **bl,** 'IdaGold' yellow mustard.

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 annual and winter annual grassy weed pressure at the study location has been reduced but remains very high, especially in replications III and IV.

In 2005 winter wheat in rotations 3 and 4 was treated with Maverick™ at 2/3 oz/ac to control downy brome (*Bromus tectorum* L.). Winter wheat in other rotations was not treated because of plant back restrictions. No additional in-crop herbicides were applied because of in climate weather and close proximity of plots increasing the potential for spray drift. 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. No herbicides were applied prior to seeding recrop winter wheat in the fall of 2004 or 2005 because of a lack of volunteer crop or weed germination. Recrop winter wheat was not seeded in 2006 because of a lack of soil moisture and very little weed and volunteer crop germination. Spring wheat was seeded instead in 2007.

In 2005 glyphosate was applied prior to seeding spring planted crops to control weeds and volunteer crops at 24oz/ac. No additional in-crop herbicides were applied to spring planted crops because of in climate weather and close proximity of plots increasing the potential for spray drift.

In 2006 and 2007 glyphosate was applied at 21 and 28 oz/ac prior to seeding spring planted crops. 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.

Chemical fallow plots were maintained mostly weed free with three herbicide applications 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 2005 glyphosate was applied on May 5 and June 24 at 24 oz/ac and 32 oz/ac on August 19. 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.

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. Overall the study location is characterized as having a heavy infestation of common rye

(*Secale cereal* L.) and a population of wild oat (*Avena fatua* L.) and downy brome. Averaged over the 3 years, replication I had less weed pressure and greater yield than replication IV (data no presented).

Winter wheat was the most variable crop in both weed control and yield over the last 3 years. In 2005, eleven winter wheat plots were removed and no yield was recorded because of severe rye infestations, in 2006 six plots were removed, and in 2007 only three plots were removed but recrop winter wheat plots were held and seeded to spring wheat. Winter wheat in rotation 4 had significantly less weed pressure than winter wheat in rotation 6 with an average score of 5.1 compared to only 3.2 (Table 1). Winter wheat in rotations 4, 5, 8 and 9 proceeded by chemical fallow and spring crop had significantly greater yield than winter wheat rotations 6, 9 and 7 seeded in recrop conditions. In the 2-year rotation 3 of winter wheat-chemical fallow, winter wheat yielded less than winter wheat produced in both 3 year crop rotations (4&5) and the yield was not significantly different than winter wheat rotations 6, 9 and 7 seeded in recrop conditions. A significant rotation x year interaction in yield was detected and was mostly caused because recrop winter wheat was not planted in 2007 and was replaced in rotation by spring wheat because of dry seeding conditions in the fall limited weed germination and poor seeding conditions.

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 33.6 bu/ac.

Similar to spring wheat, no differences in grain yield was detected in spring barley with a 3-year average yield of 1.38 ton/ac (Table 3). Differences in weed pressure were detected as spring barley following winter wheat (rotation 5) had significantly less weeds than spring barley following spring cereal in rotation 1 and rotation 7 with an average of score of 8.4 compared to only 6.7 and 6.6. Wild oat and broadleaf weed pressure was noted.

Spring grain plots were soft white spring wheat in 2005 and Dark Northern Spring wheat in 2006 and 2007. Similar to the spring wheat plots, no differences in weed pressure were detected among the spring grain treatments in rotation with an average weed pressure score of 6.94 (Table 4). Broadleaf weed pressure and wild oat populations were noted throughout the plots. Differences in grain yield were detected with spring grain in rotation 9 following winter wheat and rotation 6 following winter wheat producing greater yield over the 3 years than spring grain in rotation 8 following winter wheat at 39.4 and 39.0 bu/ac compared to only 31.6 bu/ac. Spring grain in rotation 9 following spring grain was not significantly different from the other rotations averaging 36.1 bu/ac.

Averaged over the 3 years, no differences were detected in yellow mustard within rotations in weed pressure and grain yield. Weed pressure averaged 6.53 with broadleaf weeds and wild oat populations were noted each year (Table 5). Yellow mustard over the 3 years has averaged 515 lb/ac with yield being limited by weed pressure (2005-06), herbicide damage (2007), frost (2006), and flea beetle damage (2007).

Economic Performance:

Gross economic return was determined using the average price over the past 3 years 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. Yellow mustard price was calculated using the 3-year average contract price for the region (personal communication). Over the 3 years soft white, soft white club, spring barley, and yellow mustard has averaged $5.00/bu, $5.21/bu, $143.67/ton and $0.164/lb. Dark Northern Spring wheat has averaged $5.83/bu with a $0.02/bu premium for every ¼ over 14% protein and $0.04/bu discount for every ¼ below 14% protein. Variable costs include seed, fertilizer and herbicides were established utilizing the *2003 Enterprise Budgets for Spring Barley, Spring Wheat, and Winter Wheat Using Direct Seeding Tillage Practices, Lincoln County, Washington*. Fertilizer price was increased 25% for bulk nitrogen and 31% for dry blend in 2007 to account for drastic differences in price from previous years. Additional costs, including equipment and overhead, were not includes 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 spring barley produced the highest gross return, had the highest average cost per acre, but produced the greatest economic return over costs at $147/ac, significantly greater than rotation 6, 8, 2, 7 and 3 at only $97, $96, $95, $90, and $68/ac respectfully (Table 8). 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. In 2005 and 2007 spring barley produced the greatest return over cost but in 2006 it had one of the lowest returns over costs. Rotation 3, winter wheat-chemical fallow, has the lowest average return over costs at only $68/ac and these numbers reflect the removal of 2 plots in 2007 because of severe rye infestations.

Impact of Research

To date the impact of this research has been limited as results remain preliminary as not all rotations have gone a complete cropping cycle. However, rotations containing continuous barley or a three year rotation including chemical fallow, winter wheat, and spring barley on ground with a severe rye infestation are more profitable than winter wheat, chemical fallow; continuous spring wheat; and a four year continuous crop rotation including spring wheat, barley, mustard, and winter wheat. 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 and project results remain early for wide spread dissemination to area growers and has been limited to project and rotational goals and what expected outcomes are anticipated. With that, these preliminary results were discussed at the 2007 Northern Lincoln County Extension tour and were discussed at winter grower meeting in 2006-07.

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 2005-07.

Rotation #, crop sequence	Weed Pressure (score 1-10) [a]	Grain Yield (bu/ac) Year			Mean
		2005	2006	2007	
#4 sw/cf/**ww**	5.1	80.7	42.2	58.8	60.6
#5 sb/cf/**ww**	4.5	60.3	66.4	53.2	60.0
#8 sg/bl/cf/**ww**	4.7	67.8	74.5	32.0	58.1
#9 sg/sg/cf/**ww**/ww	3.9	66.1	46.3	56.2	56.2
#3 cf/**ww**	3.6	54.4	48.5	20.9	41.3
#6 sg/bl/**ww**	3.2	8.1	36.1	42.8	29.0
#9 sg/sg/cf/ww/**ww**	3.8	23.4	15.4	42.4	27.1
#7 sw/sb/bl/**ww**	4.0	0.0	37.5	33.8	23.8
Mean	4.1	45.1	45.9	42.5	44.5
LSD $_{(0.05)}$	1.7	Sig. rotation x year interaction, LSD$_{(0.05)}$ = 17.5			

[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 2005-07.

Rotation #, crop sequence	Weed Pressure (score 1-10) [a]	Grain Yield (bu/ac) Year			Mean
		2005	2006	2007	
#4 **sw**/cf/ww	6.8	33.8	31.4	45.8	37.0
#7 **sw**/sb/bl/ww	6.8	26.5	34.6	42.4	34.5
#2 cont. **sw**	6.7	30.0	27.7	30.7	29.4
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 2005-07.

Rotation #, crop sequence		Weed Pressure (score 1-10)[a]	Grain Yield (ton/ac) Year 2005	2006	2007	Mean
#5	**sb**/cf/ww	8.4	1.55	1.28	1.57	1.44
#1	cont. **sb**	6.7	1.53	0.99	1.66	1.39
#7	sw/**sb**/bl/ww	6.6	1.45	0.93	1.42	1.30
LSD $_{(0.05)}$		1.3				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 2005-07.

Rotation #, crop sequence		Weed Pressure (score 1-10)[a]	Grain Yield (bu/ac) Year 2005	2006	2007	Mean
#9	**sg**/sg/cf/ww/ww	7.25	31.2	37.1	49.9	39.4
#6	**sg**/bl/ww	7.33	31.0	34.9	51.2	39.0
#9	sg/**sg**/cf/ww/ww	7.50	32.9	30.2	45.4	36.1
#8	**sg**/bl/cf/ww	5.67	33.8	23.8	37.2	31.6
LSD $_{(0.05)}$		n.s.				5.3

[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 mustard in various crop rotations at the WSU Wilke Farm near Davenport, WA in 2005-07.

Rotation #, crop sequence		Weed Pressure (score 1-10)[a]	Grain Yield (lb/ac) Year 2005	2006	2007	Mean
#8	sg/**bl**/cf/ww	6.08	523	298	765	528
#7	sw/sb/**bl**/ww	6.75	566	373	645	528
#6	sg/**bl**/ww	6.75	541	323	600	488
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 2005-07.

Rotation #, crop sequence	Gross Economic Return[a]			
	Year			Mean
	2005	2006	2007	
	$/ac			
#1 cont. sb	220	142	238	200
#5 sb/cf/ww	174	177	167	173
#9 sg/sg/cf/ww/ww	157	143	215	172
#4 sw/cf/ww	197	126	178	167
#6 sg/bl/ww	95	148	208	151
#2 cont. sw	149	138	152	147
#7 sw/sb/bl/ww	112	141	173	142
#8 sg/bl/cf/ww	152	144	128	141
#3 cf/ww	142	126	54	107
Mean	155	142	168	155
Sig. rotation x year interaction, $LSD_{(0.05)}$ = 24				

[a] F.O.B. price on Sept. 15 each year at Ritzville Warehouse and yearly yellow mustard contract prices were used to calculate gross economic return. Average market price for the 3 year period are as follows; soft white wheat, $5.00/bu; soft white club, $5.21/bu; DNS, $5.83/bu, premium $0.02/bu for every ¼ above 14% protein, discount $0.04/bu for every ¼ below 14% protein; barley, 143.7/ton; mustard, $0.164/lb.

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 2005-07.

Rotation #, crop sequence	Variable costs[a]			
	Year			Mean
	2005	2006	2007	
	$/ac			
#6 sg/bl/ww	38	55	68	54
#1 cont. sb	34	57	69	54
#2 cont. sw	34	52	67	52
#7 sw/sb/bl/ww	37	53	66	52
#9 sg/sg/cf/ww/ww	35	50	61	49
#8 sg/bl/cf/ww	33	45	57	45
#4 sw/cf/ww	36	42	52	43
#5 sb/cf/ww	33	37	53	41
#3 cf/ww	38	34	46	39
Mean	35	47	60	47
Sig. rotation x year interaction, $LSD_{(0.05)}$ = 1				

[a] Variable costs were established utilizing the *2003 Enterprise Budgets for Spring Barley, Spring Wheat, and Winter Wheat Using Direct Seeding Tillage Practices, Lincoln County, Washington*. EB1963E. Fertilizer price was adjusted in 2007 to represent a 25% and 31% increase in price.

Table 8. Return over variable cost of nine direct seeded crop rotations at the WSU Wilke Farm near Davenport, WA in 2005-07.

Rotation #, crop sequence		Economic Return over Variable Costs			
		Year			
		2005	2006	2007	Mean
		---------- *$/ac* ----------			
#1	cont. sb	186	85	169	147
#5	sb/cf/ww	141	140	114	132
#4	sw/cf/ww	161	84	126	123
#9	sg/sg/cf/ww/ww	122	93	154	123
#6	sg/bl/ww	57	93	140	97
#8	sg/bl/cf/ww	119	99	71	96
#2	cont. sw	115	86	85	95
#7	sw/sb/bl/ww	75	88	107	90
#3	cf/ww	104	92	8	68
Mean		120	95	108	107

Sig. rotation x year interaction, $LSD_{(0.05)}$ = 36