TITLE: Soil persistence of imazamox herbicide in tilled and direct-seeded dry land, winter wheat cropping systems.

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INTERIM or FINAL REPORT: Interim

PROJECT OBJECTIVES: 1) Determine the response of yellow mustard to imazamox herbicide persistence under conventional, minimum and direct-seed tillage systems in intermediate and high precipitation zones. 2) Determine the dissipation rate of imazamox herbicide under conventional, minimum and direct-seed tillage systems in intermediate and high precipitation zones using a yellow mustard biomass bioassay.

KEY WORDS: Imazamox, soil persistence, tillage, yellow mustard biomass bioassay

STATEMENT OF PROBLEM: Imazamox (Beyond) herbicide, a group 2 acetolactate synthase inhibitor, is used to selectively control weeds, such as jointed goatgrass, downy brome, wild oat and Italian ryegrass, in Clearfield® winter wheat. Imazamox can persist in the soil for 3 to 26 months, and thus affect growth of rotational crops such as barley, canola, and mustard. Tillage practices used in the dry land winter wheat cropping systems can affect herbicide carryover and injury to rotational crops. However, research is seldom conducted to compare potential herbicide carryover among different tillage practices and environments. Imazamox is used as a model herbicide in this study to determine the effect of an environment by tillage interaction on soil persistence of herbicides used in Pacific Northwest (PNW) dry land winter wheat production systems.

ZONE OF INTEREST: Intermediate and high rainfall, annual cropping

ABSTRACT OF RESEARCH FINDINGS:
This study is being conducted at the University of Idaho Kambitsch Research Farm near Genesee, Idaho, the Columbia Basin Agricultural Research Center near Pendleton, Oregon, and the Washington State University Wilke Farm near Davenport, Washington to determine the effect of tillage on the persistence of imazamox herbicide. Fall and spring applications of imazamox were applied at one, two, and three times the maximum labeled rate to Clearfield® ORCF-101 winter wheat. Soil samples have been collected regularly at each site since imazamox was applied in the fall and the spring, and are frozen until used in bioassay tests. Grain was harvested at all sites during summer 2006 and tillage strips were implemented in the fall 2006. 'IdaGold' yellow mustard was seeded during spring 2007 and harvested during summer 2007. Data are presented by location and separated by treatment and tillage because there was no significant treatment by tillage interactions. Imazamox applied in the fall at the two highest rates to winter wheat injured mustard 21 to 86% at all locations, while imazamox applied to winter wheat in the spring injured mustard 5 to 91%. At Pendleton, the most injury was in conventional tillage followed by minimum, with the least injury in the direct-seeded plots. At Genesee, the most injury was in minimum tillage followed by direct-seed, with the least injury in conventional tillage. At Davenport, the minimum and direct-seed tillage had

the most injury followed by conventional tillage with the least injury. This study is being repeated except soil samples are not being collected. Grain was harvested at all sites during summer 2007. Imazamox applied in the fall at the highest rate injured wheat 20 to 30% at all locations, while spring applied imazamox injured wheat 6 to 68%. No treatments adversely affected grain yield compared to the untreated control. Work on the soil bioassay has begun but no results are available.

RESULTS AND INTERPRETATION:
Procedures: Objective 1: Tillage strips were implemented in fall 2006 at field sites established in August 2005 at the University of Idaho Kambitsch Research Farm near Genesee, Idaho (high precipitation area), the Columbia Basin Agricultural Research Center near Pendleton, Oregon (intermediate precipitation area with warm temperature), and the Washington State University Wilke farm near Davenport, WA (intermediate precipitation with cooler temperatures). Tillage was done on October 11 at Pendleton, October 24 at Davenport, and October 31 at Genesee. Conventional (moldboard in fall) and minimum (chisel plow in fall) tillage strips were cultivated in the spring prior to seeding. 'IdaGold' yellow mustard was seeded at 8 lb/A on March 23, 2007 at Pendleton, 10 lb/A on April 11, 2007 at Davenport, and 10 lb/A on April 20, 2007 at Kambitsch using a Fabro no-till drill with rows spaced 7-inch apart at all three sites. Lambda-cyhalothrin (Warrior) insecticide was applied at 0.03 lb ai/A at Pendleton on April 27, 2007, and Carbaryl (Sevin) at 1 lb ai/A + R56 was applied at the Kambitsch Research Farm on May 15, 2007 for flea beetle control. Due to drift from an aerial application of propoxycarbazone (Olympus) at 0.039 lb ai/A at Davenport between April 17 and 24, mustard was re-seeded at 10 lb/A on May 23, 2007. Quizalafop (Assure II) at 0.048 lb ai/A + a nonionic surfactant at 0.25% v/v also was applied at Davenport on May 23, 2007 for grass control. Clopyralid (Stinger) was applied at 0.094 lb ae/A + 0.25% v/v nonionic surfactant at Genesee on June 4 for broadleaf control.

Visual injury was evaluated 14, 21 and 56 days after emergence of mustard plants. Plant counts were done 21 days after emergence on April 27, 2007 at Pendleton and May 24, 2007 at Genesee. Plant counts were done 56 days after emergence at Davenport on June 20, 2007. Aboveground crop biomass samples were collected from two 3.28-ft section of row randomly located within each sub-plot when the control plots reached 50% flowering. Mustard plants were counted, cut at the soil surface, placed in paper bags, dried at 60 C for 72 h, and weighed. This was done on June 1 at Pendleton, June 20 at Davenport, and June 27 at Genesee. Bifenthrin (Capture) insecticide was applied at 0.04 lb ai/A by air to the Genesee site on July 16 for aphid control. Yellow mustard was harvested at Pendleton on July 31, at Davenport on August 6, and at Genesee on August 28 using a small plot combine.

Soil samples were collected at each site as scheduled (Table 1) except the 30 days after tillage (DATillage) at Genesee and Davenport and the 90 DATillage at Davenport due to frozen ground and the 240 DATillage at Davenport due to herbicide drift. Tillage strips were implemented again (second time on plots established in fall 2005) on October 18 at Pendleton and on October 23, 2007 at both the Davenport and Genesee sites and 'IdaGold' yellow mustard will be seeded for the second consecutive year during spring 2008 using a Fabro no-till drill.

The above experiment is being repeated during the 2006-07 crop year with the exception that soil samples are not being collected. Clearfield® herbicide resistant soft white winter wheat (ORCF-101) was seeded September 12, 2006 at Davenport using a Fabro no-till drill with rows spaced 7-inches apart, October 12, 2006 at Kambitsch using a Flexi-coil 8000 NT Air Seeder with a 10 inch row spacing, and October 16, 2006 at Pendleton using a John Deere 1560 no-till drill with 7 inch row spacing. The amount of surface residue at each site was determined shortly before applying herbicide treatments in the fall by collecting residue in four randomly placed 2.69 ft^2 quadrants per replication. Samples collected within a replication were combined to form a composite sample, dried at 60 C for 48 hr, and weighed. The percent of ground cover by residue was also visibly estimated at the time of sample collection (data not shown).

Fall herbicide treatments were applied at 0.047 lb ai/A (1X), 0.094 lb ai/A (2X), and 0.14 lb ai/A (3X) on October 27 at Davenport using a small plot tractor sprayer delivering 10 gpa at 35 psi, on November 20 at Pendleton using a small plot tractor sprayer delivering 10 gpa at 20 psi, and on December 14 at Kambitsch using a backpack sprayer calibrated to deliver 10 gpa at 35 psi. All fall applications were made when the wheat had three to four leaves. Wheat injury was evaluated visually for fall-applied treatments 7, 14, and 21 DAT on a scale of 0 (no injury) to 100% (dead).

During spring 2007, treatments were applied at the 1X, 2X, and 3X rates on March 22 at Pendleton, April 26 at Davenport, and May 11 at Kambitsch. All spring applications were made then the wheat had five to six leaves and two to three tillers. Surface residue samples were collected and percent ground cover was estimated prior to herbicide application using the technique previouslydescribed. Wheat injury was evaluated visually in spring treatments 7, 14, 21, and 28 DAT. When the spring application was evaluated at 7 DAT, the fall application treatments also were evaluated. Additionally, all treatments with fall applications were evaluated periodically during the spring when injury was observable. Weed control was evaluated visually 21 and 28 DAT and at heading of grass weeds on a scale of 0 (no control) to 100% (complete control). Fluroxypyr (Starane) at 0.12 lb ai/A and bromoxynil + MCPA (Bronate Advanced) at 0.5 lb ai/A plus a nonionic surfactant at 0.25% v/v were applied at Kambitsch Farm on April 29 for broadleaf control. No broadleaf control was needed at Pendleton or Davenport. Aboveground crop biomass samples were collected from two 3.28-ft section of row randomly located within each sub-plot when the winter wheat was fully headed. Wheat plants were counted, cut at the soil surface, placed in paper bags, dried at 60 C for 72 h, and weighed. This was done on June 18 at Davenport, June 18 at Pendleton, and June 27 at Kambitsch. Winter wheat was harvested at Pendleton on July 24, Davenport on August 1, and Genesee on August 13 using a small plot combine. Tillage treatments, which are moldboard plow, chisel plow and no-tillage, were implemented on October 18 at Pendleton and on October 23 at both the Davenport and Genesee sites. 'IdaGold' yellow mustard will be seeded in plots during spring 2008 using a Fabro no-till drill.

Objective 2: When field sites were established in August 2005, about 20 kg of soil was collected at each site (Table 1). The soil is being used in the laboratory to develop standard dose response curves relating yellow mustard plant biomass to imazamox concentration in soil for each field test site. Preliminary bioassays are conducted a minimum of three times for each site. Stock herbicide suspensions are prepared by mixing 64 mg ai of imazamox into 1,000 ml of distilled water. The appropriate volume of the stock solution is pipetted into the appropriate amount of distilled water for a total volume of 15 ml and applied with an atomizer to 500 g of air-dried soil in a 33-by 40-cm plastic bag to achieve final herbicide concentrations of 0, 0.5, 1, 2, 4, 8, 16, 32, and 64 ng ai/g. The estimated concentration of imazamox in the top 20 cm of soil (approximated to weigh 2.86 million kg/ha) immediately after herbicide application is 18.5, 37, and 55.5 ng/g for the 53 (1X), 106 (2X), and 159 (3X) g ai/ha rates, respectively. Treated soil is mixed by shaking the soil in the bag for 2 minutes and allowed to air-dry for 4 hr. Six plastic 'conetainers' (3.8 cm diam by 14 cm deep) have a jumbo cotton ball placed in the bottom to prevent the soil from falling out and are filled with 80 g of treated soil to within 0.6 cm of the top. Three germinated 'IdaGold' yellow mustard seeds are placed on the soil in each tube and covered with a thin layer of potting soil. Plants in each 'conetainer' are thinned to 1 plant immediately after emergence. 'Conetainers' are placed in racks and incubated in a growth chamber at 21 C with a 16-h photoperiod for 14 days. A plastic container is placed under a group of 6 'conetainers' by treatment and filled with distilled water for sub-irrigation throughout the duration of the experiment. Treatments are arranged in a randomized complete block design with six replications. Yellow mustard biomass is collected 14 DAT. Biomass is dried at 60 C for 48 hr and weighed. The response of plant height and biomass to imazamox concentration is calculated as a fraction of the untreated control treatment and fitted to the standard curve model

$$Y = B_0 - B_1(\ln(\text{Dose} + 1)),$$

where Y is plant biomass as a fraction of the control, B_0 is the response at dose = 0, B_1 is the rate of response as dose increases, and dose is the herbicide concentration (ng/g). The equation is an exponentially decreasing curve where percent plant biomass decreases as dose increases.

Discussion of results:
Yellow mustard data are expressed as a percentage of the untreated control. Data are presented by location and separated by treatment and tillage because there were no significant treatment by tillage interactions.

Imazamox applied in the fall at the two highest rates to winter wheat injured mustard 21 to 86% at all locations, while spring-applied imazamox injured mustard 5 to 91% (Table 2). Mustard seed yield was significantly higher when the label rate of imazamox (1X) was applied in both the fall and spring at Pendleton compared to all other treatments. Due to an infestation of prickly lettuce (*Lactuca serriola* L.) at Genesee, the data are unbalanced and therefore LSDs are not reported for yield. Seed yield was reduced least by the 1X fall and spring applications of imazamox compared to other treatments at Genesee. At the Davenport site, the 1X and 2X imazamox rates applied in the fall had significantly higher mustard yield than all other treatments. However, data from Davenport were affected by drift from an aerial application of propoxycarbazone (Olympus) at 0.039 lb ai/A that occurred between April 17 and 24, 2007.

At Pendleton, mustard was injured most in conventional tillage followed by minimum tillage with the least injury in the direct-seeded plots (Table 3). Wheat residue was removed from the direct-seeded plots in fall 2006, which likely allowed for more microbial degradation of the herbicide compared to other tillage treatments. At Genesee, mustard was injured most in minimum tillage followed by direct-seed, with the least injury in conventional tillage. At

Davenport, the minimum and direct-seed tillage had the most injury followed by the conventional tillage with the least injury. At Pendleton, yield was different among all tillage treatments, with the highest seed yield in the direct seeded treatment. At Genesee, yield in conventional tillage was highest followed by direct-seed and minimum tillage. At Davenport, minimum tillage had significantly less yield than conventional and direct-seed tillage. Seed yield was not different between the fall and spring imazamox applications at Pendleton and Genesee (Tables 4 and 5). At Davenport, spring affects were always greater than fall for injury, plant counts, biomass and yield. Injury was always greater for the 2X versus the 1X application rates at all locations. The effect of the 1X application rate compared to the 2X and 3X rates was always significantly less for injury, plant counts, biomass and yield at both the Pendleton and Davenport, but only for injury and biomass at Genesee.

This study is being repeated except soil samples are not being collected. Imazamox applied in the fall at the highest rate injured wheat 20 to 30% at all locations, while spring applied imazamox injured wheat 6 to 68% (Tables 6-8). No grass weeds were present at the Genesee or Davenport. At Pendleton, downy brome (*Bromus tectorum* L.) was controlled 90 to 100% by all imazamox treatments. Grain was harvested at all sites during summer 2007. No treatments adversely affected grain yield compared to the untreated control.

IMPACTS OF RESEARCH: This study will serve as a model to determine the effect of an environment by tillage interaction on soil persistence of herbicides used in PNW dryland winter wheat production systems. More specifically, this research will determine which tillage system is best suited to reduce the amount of herbicide carryover injury to crops grown in rotation with Clearfield® winter wheat. This in turn will benefit farmers who choose to have Clearfield® winter wheat in their crop rotations.

INTERACTION (COOPERATION) WITH OTHER SCIENTISTS CONDUCTING RELATED ACTIVITY: Consulted with Aaron Esser (WSU) on establishing sites for both years and about equipment that is available for use at Wilke Farm. Also consulted with Larry Bennett and Dan Ball (OSU) regarding the Columbia Basin Agricultural Research Center site, Rod Rood and Joe Yenish (WSU) regarding the Wilke farm site, and Roy Patten, Brad Bull, and Dave Hoadley (UI) regarding the Kambitsch farm site.

PUBLICATIONS AND PRESENTATIONS:

Rood, J.R., D. Thill, D. Ball, and J. Yenish. 2007. Tillage affects imazamox persistence in soil. Western Society of Weed Science Meeting, Portland, OR, March 13.

Rood, J.R and D.C. Thill. 2007. Tillage affects Beyond herbicide persistence in soil. Columbia Basin Agricultural Research Center Field Day, June 12.

Rood, J.R. 2007. Tillage affects Beyond herbicide persistence in soil. University of Idaho Weeds Science Field Day, June 14.

Table 1: Soil sample dates for all three imazamox soil persistence study sites.

	Davenport	Genesee	Pendleton
Fall Application	18-Oct-05	2-Nov-05	2-Nov-05
Pre-spray	16-Oct-05	1-Nov-05	2-Nov-05
2 hr AT	18-Oct-05	2-Nov-05	2-Nov-05
30 DAT	22-Nov-05	13-Dec-05	30-Nov-05
90 DAT	9-Jan-06	26-Jan-06	31-Jan-06
150 DAT	7-Mar-06	30-Mar-06	29-Mar-06
210 DAT	18-May-06	1-Jun-06	31-May-06
330 DAT	12-Sept-06	25-Sept-06	25-Sept-06
Spring Application	27-Apr-06	25-Apr-06	3-Mar-06
Pre-spray	27-Apr-06	25-Apr-06	2-Mar-06
2 hr AT	27-Apr-06	25-Apr-06	3-Mar-06
11 DAT	7-May-06	5-May-06	14-Mar-06
22 DAT	18-May-06	17-May-06	24-Mar-06
45 DAT	6-Jun-06	9-Jun-06	17-Apr-06
90 DAT	27-Jul-06	24-Jul-06	1-Jun-06
135 DAT	11-Sept-06	9-Sept-06	17-Jul-06
180 DAT	26-Oct-06	24-Oct-06	23-Aug-06
Both Applications	---	---	---
Before tillage	24-Oct-06	30-Oct--06	10-Oct-06
After tillage	24-Oct-06	8-Nov-06	13-Oct-06
30 DATillage	N/A	N/A	9-Nov-06
90 DATillage	N/A	1-Mar-07	9-Jan-07
Pre-seeding	6-Apr-07	10-Apr-07	19-Mar-07
240 DATillage	N/A	10-Jul-07	7-Jun-07

Table 2: Mustard injury, plant counts, biomass, and yield by application timing and rate as a percentage of the untreated control.

			Pendleton				Genesee				Davenport			
Treatment	Rate	Application timing	Injury	Plants	Biomass	Yield	Injury	Plants	Biomass	Yield[1]	Injury	Plants	Biomass	Yield
	lb ai/A		%	%	%	%	%	%	%	%	%	%	%	%
Imazamox	0.047	Fall	1	94	82	109	42	107	84	83	41	98	108	93
Imazamox	0.094	Fall	21	112	53	82	64	130	44	50	50	100	90	94
Imazamox	0.140	Fall	40	128	45	69	86	124	25	49	60	109	71	63
Imazamox	0.047	Spring	5	123	88	112	50	110	108	77	57	96	85	70
Imazamox	0.094	Spring	27	128	48	76	71	100	45	35	81	62	76	43
Imazamox	0.140	Spring	49	127	27	60	86	94	28	35	91	30	24	31
LSD (0.05)			7	24	14	19	11	33	38	---	12	31	39	19

[1]LSD could not be calculated because of unbalanced data.

Table 3: Mustard injury, plant counts, biomass, and yield by tillage as a percentage of the untreated control.

	Pendleton				Genesee				Davenport			
Tillage	Injury	Plants	Biomass	Yield	Injury	Plants	Biomass	Yield[1]	Injury	Plants	Biomass	Yield
	%	%	%	%	%	%	%	%	%	%	%	%
Conventional	32	130	45	62	58	151	73	70	56	73	81	74
Minimum	23	114	64	78	73	112	35	29	67	85	85	54
Direct-seed	16	112	62	114	69	69	60	66	67	90	61	68
LSD (0.05)	10	NS	3	14	10	49	32	---	13	15	39	11

[1]LSD could not be calculated because of unbalanced data.

Table 4: Mustard injury, biomass, plant counts, and yield contrasts.

	Pendleton				Genesee				Davenport			
Contrasts	Injury	Plants	Biomass	Yield	Injury	Plants	Biomass	Yield	Injury	Plants	Biomass	Yield
	%	%	%	%	%	%	%	%	%	%	%	%
	----------P-Values----------											
Fall vs. Spring	0.0044	0.0353	0.1403	0.4833	0.1137	0.0481	0.3854	0.6408	<.0001	<.0001	0.0157	<.0001
1X vs. 2X	<.0001	0.1715	<.0001	<.0001	<.0001	0.5681	0.0003	0.1318	0.0004	0.1665	0.3152	0.0618
1X vs. 2&3X	<.0001	0.0415	<.0001	<.0001	<.0001	0.7076	<.0001	0.0827	<.0001	0.0278	0.0108	0.0002

DF=1

Table 5: Mustard injury, biomass, plant counts, and yield contrast means.

	Fall vs. Spring[1]				1X vs. 2X[2]				1X vs. 2&3X[3]			
	Injury	Plants	Biomass	Yield	Injury	Plants	Biomass	Yield	Injury	Plants	Biomass	Yield
	%	%	%	%	%	%	%	%	%	%	%	%
Pendleton	21/27	111/126	60/54	87/83	3/16	109/120	85/51	111/79	3/34	109/124	85/43	111/72
Genesee	64/69	120/101	51/60	61/49	46/68	109/115	96/45	80/43	46/77	109/112	96/36	80/42
Davenport	50/76	102/63	90/62	83/48	49/66	97/81	97/83	82/69	49/71	97/75	97/65	82/58

[1]Numbers to the left of the slash represent means for fall while numbers to the right of the slash represent means for spring.
[2] Numbers to the left of the slash represent means for 1X while numbers to the right of the slash represent means for 2X.
[3]Numbers to the left of the slash represent means for 1X while numbers to the right of the slash represent means for 2&3X.

Table 6: Wheat injury, head number, biomass, grain yield and test weight, and weed control in imazamox soil persistence studies near Genesee, ID.

		Application	Wheat	Weed	Wheat			
Treatment	Rate	timing	Injury[1]	Control[2]	Heads[3]	Biomass	Yield	Test weight
	lb ai/A		%	%	heads/m	grams/m	bu/A	lb/bu
Imazamox	---	Untreated	---	---	129	292	86	61.7
Imazamox	0.047	Fall	0	---	105	232	93	61.3
Imazamox	0.094	Fall	0	---	122	276	103	61.5
Imazamox	0.140	Fall	25	---	113	255	102	61.7
Imazamox	0.047	Spring	10	---	106	252	99	61.4
Imazamox	0.094	Spring	18	---	109	250	97	61.8
Imazamox	0.140	Spring	36	---	103	233	103	61.7
LSD (0.05)			10	---	21	49	NS	NS

[1]Wheat injury was evaluated seven days after spring application on May 18, 2007. Means are pooled over tillage because tillage is not yet a factor.
[2]No grass weeds were present to evaluate for weed control.
[3]Average number of heads/m on June 27, 2007.

Table 7: Wheat injury, head number, biomass, grain yield and test weight, and weed control in imazamox soil persistence studies near Davenport, WA.

		Application	Wheat	Weed	Wheat			
Treatment	Rate	timing	Injury[1]	Control[2]	Heads[3]	Biomass	Yield	Test weight
	lb ai/A		%	%	heads/m	grams/m	bu/A	lb/bu
Imazamox	---	Untreated	---	---	96	216	67	61.6
Imazamox	0.047	Fall	0	---	105	232	64	61.4
Imazamox	0.094	Fall	0	---	97	212	67	61.4
Imazamox	0.140	Fall	20	---	98	206	69	61.4
Imazamox	0.047	Spring	0	---	102	227	69	61.6
Imazamox	0.094	Spring	0	---	108	245	69	61.5
Imazamox	0.140	Spring	28	---	108	227	70	61.6
LSD (0.05)			10	---	NS	NS	6	NS

[1]Wheat injury was evaluated 14 days after spring application on May 10, 2007. Means are pooled over tillage because tillage is not yet a factor.
[2]No grass weeds were present to evaluate for weed control.
[3]Average number of heads/m on June 18, 2007.

Table 8: Wheat injury, head number, biomass, grain yield and test weight, and weed control in imazamox soil persistence studies near Pendleton, OR.

		Application	Wheat	Weed	Wheat			
Treatment	Rate	timing	Injury[1]	Control[2]	Heads[3]	Biomass	Yield	Test weight
	lb ai/A		%	%	heads/m	grams/m	bu/A	lb/bu
Imazamox	---	Untreated	---	---	56	150	59	55.4
Imazamox	0.047	Fall	1	90	93	290	61	55.2
Imazamox	0.094	Fall	13	95	95	294	62	54.9
Imazamox	0.140	Fall	30	95	86	284	64	56.0
Imazamox	0.047	Spring	6	99	102	307	60	55.6
Imazamox	0.094	Spring	29	100	118	278	62	55.8
Imazamox	0.140	Spring	68	100	100	216	59	55.6
LSD (0.05)			10	4	27	71	NS	.9

[1]Wheat injury was evaluated 28 days after spring application on April 26, 2007. Means are pooled over tillage because tillage is not yet a factor.
[2]Downy brome control was evaluated on June 11, 2007.
[3]Average number of heads/m on June 18, 2007.