Final Report

TITLE: Confirmation and Characterization of Herbicide Resistant Weed Populations in Potato Production areas of the Columbia Basin

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REPORTING PERIOD: Jan. 2011 – Dec., 2011

ACCOMPLISHMENTS:

Weed biotypes were collected from escape weeds in potato fields throughout the Columbia Basin in 2010 and were tested for susceptibility to metribuzin, rimsulfuron, clethodim, and sethoxydim potato herbicides. About 2/3 of pigweed and 1/3 of common lambsquarters biotypes collected from numerous potato and one sweet corn field exhibited resistance to metribuzin. No resistance to rimsulfuron was observed in the pigweed biotypes collected. All common lambsquarters biotypes collected have shown similar or greater susceptibility to rimsulfuron as a standard control biotype, but lambsquarters are being retested at higher rimsulfuron doses. Barnyardgrass, green foxtail, and wild proso millet biotypes collected in potato and mint fields were susceptible to normal rates of clethodim and sethoxydim.

These results confirm the presence of metribuzin resistance in the Columbia Basin potato growing region. All metribuzin resistant pigweed and common lambsquarters biotypes were cross resistant to terbacil, the main herbicide used in mint production. All pigweed biotypes resistant to metribuzin were controlled preemergence by normal use rates of other potato herbicides with other modes of action (rimsulfuron, ethalfluralin, EPTC, s-metolachlor, dimethenamid-p, trifluralin, and flumioxazin). This information could be used to improve management of herbicide resistant weed populations and to delay development of herbicide resistant weed populations.

RESULTS:

In 2010, seed of five different weed species from potato fields throughout the Columbia Basin in Washington were collected to ascertain the presence of herbicide resistant weeds. Weed seed was collected from escape weeds in potato fields throughout the Columbia Basin from Paterson (furthest SW) to Quincy (furthest NW) and from Bruce (furthest NE) to Ice Harbor (furthest SE) in 2010. Redroot pigweed (*Amaranthus retroflexis*), Powell amaranth (*A. powellii*), and common lambsquarters were the most prevalent weeds observed in late summer and were collected from over 30 fields (Table xx). Kochia and Russian thistle were observed in some fields, but at the time of seed collection (prior to potato harvest) plants had immature seed. Other species collected included hairy nightshade (4 fields), barnyardgrass (2 fields), and green foxtail (1 field). Seed from escape weeds was also collected in a sweet corn field and a dry bean field, and numerous mint fields in 2010. All seed collection sites were georeferenced.

Weed seed was cleaned and planted in greenhouse flats. Each biotype was planted in 10 cm diameter containers replicated 4 to 6 times and grown in the greenhouse. Pigweed and common lambsquarters seedlings were thinned to eight plants per pot prior to applying the herbicides.

Broadleaf weeds were treated with postemergence applied herbicides when they reached the 3 to 4 leaf stage and 1 to 2 inches tall. Grass weeds were treated when they reached the 3 to 4 leaf stage and were 3 to 4 inches tall. A single nozzle (80015 E) bench sprayer calibrated to deliver 25 GPA was used to apply herbicides treatments to plants.

Initially, weed biotypes were treated with a ½ X and 1X labeled rate of the specific herbicide in question. A susceptible biotype of each species was included in each experiment as a control. Weed biotypes that were not completely killed by the ½ X or 1X rate of the herbicide were further tested with a range of six to eight doses of the herbicide to determine the dose response of the resistant biotype compared to the susceptible control. The number of surviving seedlings, dry weights, and visual control rating were recorded at two weeks after herbicide application.

Dose response curves of each weed biotype were compared to the susceptible biotype (indigenous population) of the same species. The (also known as GR_{50} = dose required to reduce growth or shoot weight by 50% relative to untreated plants) of the resistant and susceptible populations was determined using the log logistic analysis package of the 'R' statistical program. The dose required to provide 90% control (was also calculated from the dose response curve. The relative resistance of each biotype to the susceptible control was calculated by ratio of the calculated I_{90} of the resistant biotype to the I_{90} of the susceptible biotype.

Weed biotypes with confirmed resistance were further tested for susceptibility to herbicides with other modes of action that are labeled in potato. Seeds were planted in 10 cm diameter pots and treated with normal labeled rates of each herbicide either preemergence (trifluralin, pendimethalin, EPTC, metolachlor, dimethenamid-P, flumioxazin) or postemergence (rimsulfuron). A normal susceptible biotype was included as a control for comparison in each experiment.

Redroot pigweed (*Amaranthus retroflexis*) and Powel amaranth (*A. powellii*).

Fifteen of 27 pigweed biotypes tested were resistant to metribuzin (Tables 1 and 2). Dose response analysis based on I_{90} values (dose required to provide 90% control) indicated that a 2 to 142 fold herbicide dose was required to provide 90% control the resistant biotypes compared to the susceptible control (Table 2 and Fig. 1).

Weed seed was also collected from escape weeds in mint fields in 2010. Pigweed from mint fields in the Columbia Basin were screened for resistance to terbacil, a photosystem II inhibitor herbicide that has a similar mode of action to metribuzin. Nine of 22 pigweed biotypes from mint tested resistant to terbacil (Table 1). In subsequent tests, all terbacil resistant pigweed biotypes were also resistant to metribuzin. Likewise, the 15 metribuzin resistant pigweed biotypes from potato and sweet corn fields were confirmed cross resistant to terbacil. Triazine (metribuzin) and uracil (terbacil) herbicides inhibit P.S. II in plants by binding to the Qb protein in the chloroplast and inhibit electron transport. These two herbicide families have overlapping binding sites and similar mutations in the Qb protein typically confer resistance to both herbicide families.

All 27 pigweed biotypes collected from potato, sweet corn, and dry bean fields were susceptible to rimsulfuron (Matrix) at 0.012 lb ai/a (1/2x field use rate).

In greenhouse studies, flumioxazin (Chateau), EPTC (Eptam), dimethenamid-P (Outlook), s-metolachlor (Dual Magnum), ethalfluralin (Sonalan), and trifluralin (Treflan) applied preemergence at normal use rates all controlled metribuzin resistant pigweed biotypes. Susceptibility of metribuzin resistant pigweed to pendimethalin (Prowl) at 0.75 lb ai/a was less than that of other preemergence herbicides, but the metribuzin resistant pigweed biotypes were suppressed by pendimethalin equal to the normal susceptible biotype. In additional studies, all terbacil resistant pigweed biotypes from mint were susceptible to postemergence applied bromoxynil (Buctril) at 0.5 lb ai/a and bentazon (Basagran) at 1 lb ai/a similar to the susceptible control.

Common lambsquarters (*Chenopodium album*)

Eight of 25 common lambsquarters biotypes collected from potato fields in the Columbia Basin were resistant to metribuzin (Tables 1 and 3). Metribuzin dose response trials were conducted with seven doses ranging from 0.022 to 10.5 lbs ai/a (Fig 2). Even the lowest dose of 0.022 lb ai/a resulted in 92% control of the susceptible biotype. Dose response analysis based on I_{90} values indicated that approximately 40 to 70 times as much herbicide was required to provide 90% control the resistant biotypes compared to the susceptible control (Table 3). Dose response of the susceptible biotype is being repeated with a lower dose range in order to calculate the I_{50} and I_{90} values and obtain more accurate relative resistance ratios of the resistant biotypes to the susceptible biotype. All metribuzin resistant common lambsquarters biotypes from potato tested cross resistant to terbacil.

All 27 common lambsquarters biotypes were tested for susceptibility to rimsulfuron (Matrix) applied POST at 0.0117 lb ai/a (1/2x field use rate) plus methylated seed oil (MSO). No biotypes were completely killed with rimsulfuron at this low rate and control ranged from 57 to 93% at 2 WAT. All lambsquarters biotypes collected appeared equal to or slightly more susceptible than the susceptible control, suggesting that none of these biotypes may be considered resistant to rimsulfuron. Common lambsquarters is semi tolerant to rimsulfuron and higher doses are required to kill the weed compared to more highly susceptible species, such as pigweed. Trials are being repeated at a higher dose and applied preemergence.

One additional common lambsquarters biotype was collected from a potato field in 2011 and has not undergone testing yet.

Hairy Nightshade (*Solanum physalifolium* – formerly *S. sarrachoides*)

Four hairy nightshade biotypes collected from potato fields in the Columbia Basin were susceptible to rimsulfuron (Matrix) applied POST at 0.0117 lb ai/a (1/2x field use rate) plus methylated seed oil (MSO). All hairy nightshade biotypes collected appeared equal to or slightly more susceptible than the susceptible control biotype, suggesting that none of these biotypes are resistant to rimsulfuron.

Grass weeds (barnyardgrass *Echinochloa crus-galli*, green foxtail *Setaria viridis*, and wild proso millet *Panicum miliaceum*)

Three grass species were collected from mint and potato fields; green foxtail, barnyardgrass, and wild proso millet and were screened for susceptibility to clethodim (Select) and sethoxydim (Poast), two postemergence grass herbicides with similar mode of action.

Grass seedlings were treated with each herbicide when seedlings reached 3 to 4 leaf stage and a susceptible biotype (collected from areas with no known herbicide resistance) of each species was included in each experiment. All of the grass weed biotypes collected from mint and potato fields were susceptible to either the 0.5 or 1 x field use rate of clethodim and sethoxydim and the response was similar to that of the susceptible control biotypes (Table 4). None of these grass populations appear to be resistant to this group of postemergence grass herbicides.

Kochia (*Kochia scoparia*).
The response of three kochia biotypes collected from mint fields to mint herbicides has not been tested yet. Seed of an additional kochia biotype was collected from a potato field in 2011 and has not been tested yet.

PUBLICATIONS: None

PRESENTATIONS & REPORTS:
June 20, 2010. Columbia Basin Crop Consultants Meeting, Moses Lake, WA. Managing herbicide resistant weeds.
Nov. 18, 2010. Pacific Northwest Vegetable Association Conference, Kennewick, WA. Managing herbicide resistant weeds.
Nov. 30, 2011. Hermiston Farm Fair, Hermiston, OR. Herbicide resistant weeds in mint and potato production.

Table 1. Weed seed collected from escape weed populations in potato, mint, and other fields throughout the Columbia Basin in 2010-11.

Crop	Weed Species	Binomial	Number of Biotypes	Number Resistant	Herbicide
2010					
Potato	Pigweed	*Amaranthus retroflexis, A. powellii*	25	15	metribuzin
	C. lambsquarters	*Chenopodium album*	25	8	metribuzin
	Hairy nightshade	*Solanum physalifolium*	4	0	rimsulfuron
	Barnyardgrass	*Echinochloa crus-galli*	2	0	sethoxydim/ clethodim
	Green foxtail	*Setaria viridis*	1	0	sethoxydim/ clethodim
Sweet Corn	Pigweed	*A. retroflexis*	1	1	metribuzin

Dry bean	Pigweed	*A. retroflexis*	1	0	metribuzin
	C. lambsquarters	*C. album*	1	na	
Mint	Pigweed	*A. retroflexis, A. powellii*	22	9	terbacil
	C. lambsquarters	*C. album*	1	na	
	Barnyardgrass	*E. crus-galli*	3	0	sethoxydim/ clethodim
	Green foxtail	*S. viridis*	10	0	sethoxydim/ clethodim
	Kochia	*Kochia scoparia*	3	na	
	C. groundsel	*Senecio vulgaris*	1	1	terbacil
	Horseweed	*Conyza Canadensis*	1	1	paraquat
	Wild proso millet	*Panicum miliaceum*	1	0	sethoxydim/ clethodim
	Quackgrass	*Elymus repens*	1	0	sethoxydim/ clethodim/ quizalofop
2011					
Blueberry	Horseweed	*C. canadensis*	1	na	
Potato	Kochia	*K. scoparia*	1	na	
Onion	C. lambsquarters	*C. album*	1	na	
Potato	C. lambsquarters	*C. album*	1	na	

na = no data available yet or seed not viable.

Table 2. Response of 27 pigweed biotypes collected from Washington potato fields to postemergence applied metribuzin in the greenhouse. Second and third columns are control observed in initial screen. I_{50} = dose required to reduce growth by 50% and I_{90} = dose required to reduce growth by 90% and were calculated from dose response studies. Numbers in parenthesis are relative resistance to susceptible control.

Biotype	Percent Injury (2 WAT)		I_{50}	I_{90}
	(.175 lb ai/a)	(.35 lb ai/a)	(lb ai/a)	(lb ai/a)
Susc. CK	98	100	0.013	0.036
P1	90-100	100	--	--
P2	**5**	**18**	**1.4 (108x)**	**5.1 (142x)**
P3	100	100	--	--
P4	**5**	**34**	**1.3 (100x)**	**3.4 (94x)**
P5	**27**	**56**	**0.4 (31x)**	**2.7 (75x)**
P6	**16**	**46**	**0.5 (38x)**	**1.9 (53x)**
P7	88-100	100	--	--
P8	100	100	--	--
P9	87-99	100	--	--
P10	**10**	**14**	**1.3 (100x)**	**3.4 (94x)**
P11	**21**	**28**	**0.6 (46x)**	**2.0 (56x)**
P12	**6**	**18**	**1.2 (92x)**	**2.4 (67x)**
P13	**6**	**20**	**0.6 (46x)**	**2.1 (58x)**
P14	**4**	**27**	**1.4 (108x)**	**4.0 (111x)**
P15	99	99	--	--
P16	86-99	100	--	--
P17	**51**	**87**	**0.09 (7x)**	**1.2 (33x)**
P18	**64**	**72**	**0.06 (5x)**	**0.9 (25x)**
P19	89-100	100	--	--
P20	**4**	**13**	**1.3 (100x)**	**2.6 (72x)**
P21	92	--	--	--
P22	**59**	**--**	**0.04 (3x)**	**0.08 (2x)**
P23	94	--	--	--
P24	87	--	--	--
P25	**4**	**--**	**0.8 (62x)**	**2.1 (58x)**
P26	81	--	--	--
P27	**7**	**--**	**0.6 (46x)**	**1.8 (50x)**

Biotypes in boldface tested resistant to metribuzin.

P20 – collected from sweet corn. P26 – collected from dry bean field.

Figure 1. Dose response of six metribuzin resistant pigweed biotypes collected from Washington potato (P2, P4, P10, P12, and P14) and sweet corn (P20) fields in 2010 compared to a susceptible control.

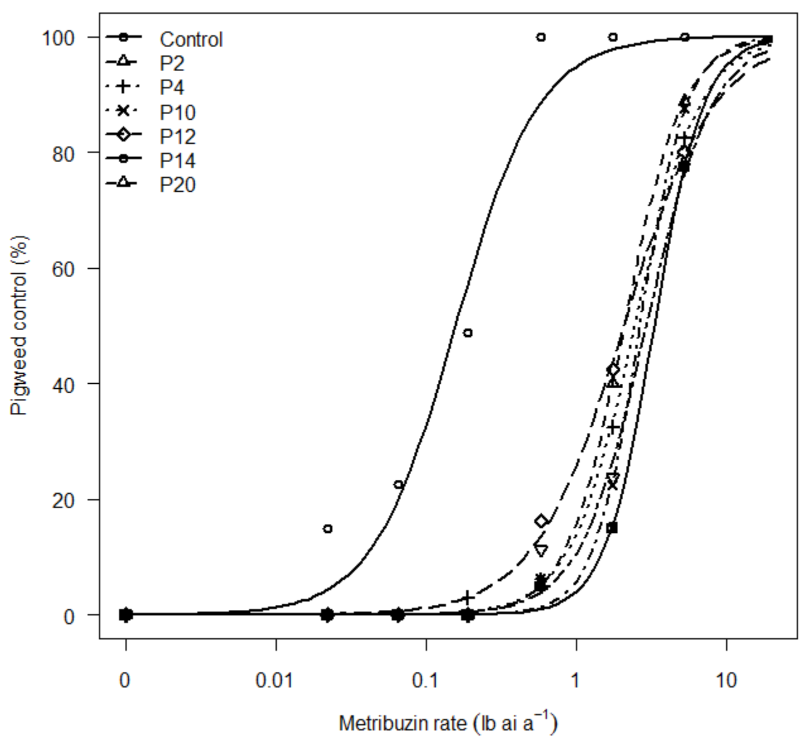

Table 3. Response of 27 common lambsquarters biotypes collected from Washington potato fields to postemergence applied metribuzin in the greenhouse. Second column is control observed in initial screen. I_{50} = dose required to reduce growth by 50% and I_{90} = dose required to reduce growth by 90% and were calculated from dose response studies. Numbers in parenthesis are relative resistance to susceptible control.

Biotype	Initial Screen Percent Injury (2 WAT)	I_{50}	I_{90}
	(0.175 lb ai/a)	(lb ai/a)	(lb ai/a)
Susc. CK	100	<0.022	~0.022
P31	100	--	--
P32	**19**	**0.13**	**0.86**
P33	**7**	**0.21**	**1.3**
P34	**12**	**0.17**	**0.86**
P35	**9**	**0.22**	**1.0**
P36	100	--	--
P37	**10**	**0.25**	**1.1**
P38	100	--	--
P39	**5**	**0.38**	**1.2**
P40	100	--	--
P41	100	--	--
P42	100	--	--
P43	100	--	--
P44	100	--	--
P45	**5**	**0.44**	**1.5**
P46	100	--	--
P47	100	--	--
P48	100	--	--
P49	100	--	--
P50	100	--	--
P51	100	--	--
P52	**5**	**0.43**	**1.3**
P53	100	--	--
P54	100	--	--
P55	100	--	--
P56	na	--	--
P57	na	--	--

Biotypes in boldface tested resistant to metribuzin.
P57 – collected from dry bean field.
na – not tested yet due to small quantity seed or poor germination.

Figure 2. Dose response of eight metribuzin resistant common lambsquarters biotypes collected from Washington potato fields in 2010. The susceptible control was controlled 92% at the 0.022 lb ai/a rate (not shown).

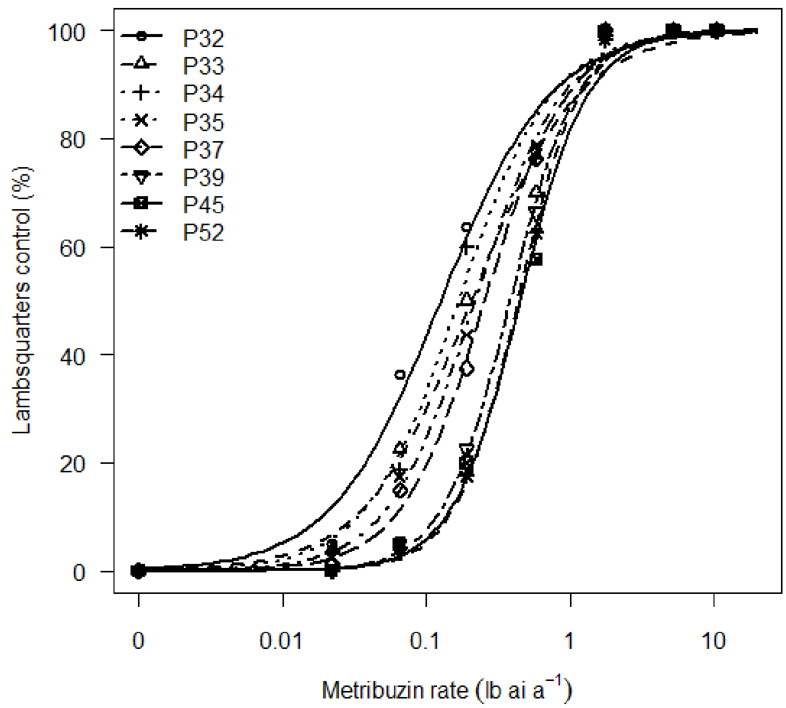

Table 4. Response of barnyardgrass, green foxtail, and wild proso millet biotypes collected from Washington mint (M) and potato (P) fields to sethoxydim (Poast) and clethodim (Select) at two doses in greenhouse trials. Units are lbs ai/acre.

	Percent Control (2 WAT)			
	Sethoxydim		Clethodim	
Species/Biotype	0.125	0.25	0.047	0.094
	(%)	(%)	(%)	(%)
Barnyardgrass				
Susceptible control	99	100	65	97
M23	99	100	83	100
M24	99	100	78	99
M25	99	99	74	99
P28	99	99	74	96
P29	99	100	80	100
Green foxtail				
Susceptible control	98	100	80	90
M26	97	--	96	99
M27	92	99	87	96
M28	96	100	97	99
M29	92	99	96	98
M30	94	95	96	98
M31	91	98	96	98
M32	97	100	97	98
M33	97	99	97	98
M34	98	--	99	99
M35	100	100	97	99
P30	99	--	97	99
Wild proso millet				
Susceptible control	100	100	90	97
M42	100	100	91	100

Crop oil concentrate (COC) was included in all treatments at 1% (v/v).