Project Report to the Oregon Association of Nurserymen

Title: Assessing weed management needs in Oregon nurseries

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Project Background and Justification

The diversity of the nursery industry in Oregon presents a wide array of weed management challenges. These challenges range from weeds such as liverwort in potted plants in greenhouses to the usual array of annual and perennial weeds present in field situations, such as pigweed, lambsquarters, annual bluegrass, and Canada thistle. Although competition from these species is often a concern, a thornier problem is contamination of shipped materials with weed seeds and vegetative propagules. Compounding the difficulty of managing theses weedy species is the fact that weed populations are seldom stable because of applied selection pressures that select for tolerant species and in some cases cause the evolution of herbicide resistant populations. Emerging issues in nurseries are the proliferation of annual bluegrass that may be resistant to preemergence herbicides and marestail (*Conyza canadensis*) that may be resistant to glyphosate. In contrast to these developments, new herbicide mode of action discovery has stagnated over the last 2 decades. With the exception of indaziflam (Bayer), no new mode-of-action herbicides have been released in the past decade.

Project Objectives and Activities

1. Identify the current weed management research needs of the nursery industry through surveys, site visits, and informal discussions.
2. Initiate at least four demonstration and/or research plots in production fields to facilitate discussion, identification, and prioritization of weed management issues.
3. Preliminary screen to determine whether marestail (*Conyza canadensis*) has elevated levels of glyphosate tolerance.

Activities

1. Survey of weed management issues in nurseries

A survey tool was developed and distributed online to nursery owners and managers in Western Oregon (see attached questionnaire and summary). Queries focused on priority weed issues in field-grown, container-grown, and greenhouse nursery systems. There were 52 responses with the majority listing field grown and bare root operations as primary operations and greenhouses as secondary operations. Compared to other management issues in nursery production, weed management was given a rating of 4.0 of 5 (5=most important). This was a voluntary survey, however, and may be biased towards those interested in weed management, specifically those with field or container operations.

Twenty eight species were mentioned as important with northern willowherb, western bittercress, and liverwort getting the most votes of importance of the 138 responses (Table 1). Other significant species listed were groundsel, yellow nutsedge, pearlwort, pigweed, and annual bluegrass. There was only one reference to marestail (*Conyza canadensis*), a weed that is becoming prevalent in many field operations.

Table 1. Survey results for weed species of most importance in nursery systems.

	Weed	Entries
1	Northern willowherb	21
2	Western bittercress	18
3	Liverwort	18
4	Groundsel	11
5	Yellow nutsedge	11
6	Pearlwort	8
7	Pigweed	8
8	Annual bluegrass	8

Herbicide resistance is common in many crops of the Willamette Valley, and respondents were asked to select from a list those herbicides that are used regularly but that do not control weeds as well as they believe they once did. Surflan (oryzalin), a Group 3 herbicide was at the top of the list with 12 responses, followed by Gallery (11 responses) and BroadStar (flumioxazin) and Devrinol (napropamide) with 7 responses each (Table 2). There

are very few cases of weeds developing resistance to herbicides in Groups 3 and 21. Screening for resistance of Group 3 herbicides may be warranted, even though it is likely that the perceived lack of control is due to weed population shifts because of the widespread use of these herbicides, rather than evolved resistance. At a minimum, herbicides should be rotated to avoid the potential of developing resistance to herbicides of Group 3, as these tools play an extremely important role in current weed management efforts.

A separate question in the survey addressed the potential development of glyphosate resistance. Some respondents indicated that annual bluegrass was the most likely weed species to have developed resistance (7 responses), but also noted that willow herb is more difficult to control with glyphosate than when glyphosate was first available for use (3 responses). Annual ryegrass only received 2 votes, even though glyphosate is used extensively and producers in other cropping systems noted a significant decrease in glyphosate effectiveness (e.g. annual ryegrass in hazelnuts). Several respondents noted that glyphosate resistance is simply not an issue.

The last question asked respondents to identify future research and education needs. Responses primarily targeted herbicide efficacy and crop safety and the control of specific weeds within specialized production systems. Less emphasis was recommended for understanding how weed biology and cultural practices could be used to manage weed populations.

Table 2. Herbicides listed by respondents that are regularly used but do not control weeds as well as the once did.

Product name	Common name	Mode of Action	Responses
Select/Shadow	Clethodim	1	4
Segment	Sethoxydim	1	1
Surflan	Oryzalin	3	12
Pendulum	Pendimethalin	3	3
Dimension	Dithiopyr	3	2
Barrier	Prodiamine	3	1
Kerb	Pronamide	3	1
2,4-D	-	4	1
Princep	Simazine	5	3
BroadStar	Flumioxazin	14	7
Ronstar	Oxadiazon	14	5
Devrinol	Napropamide	15	7
Tower	Dimethenamid	15	2
Pennant	S-metolachlor	15	1
Casoron	Dichlobenil	20	2
Gallery	Isoxaben	21	11

2. Follow up interviews and demonstration field sites.

Follow up interviews were conducted with four cooperating producers and demonstration plots initiated at 6 field sites. The objective was to better understand the complexities of day to day operations and the challenge presented by weeds in nursery production. First and foremost it became apparent that there are three to four weed management windows for field grown plants over the course of a year. Herbicides play a critical role in managing weed populations but even when rotated to the best advantage there are always weed escapes that necessitate manual removal at significant expense.

Four production sites were selected for demonstration and testing of currently used and potentially new approaches to weed management. Treatments reflected interests of cooperating growers as garnered from interviews what took place in the spring. Each site represented a completely unique system and time frame and fields were selected so that common treatments would be spread out from spring through fall.

May 2012, Canby

The first site was established in April 2012 at a conifer nursery and a number of products and use patterns were screened for efficacy and crop safety. Trees were planted on May 21, and preemergence surface (PES) herbicides were applied after wrenching on May 30 to trees that were about to break dormancy. POST herbicides were applied on June 29. Herbicides were applied with a CO2 powered back pack sprayer delivering 20 GPA at 25 to 30 PSI and with a 3 nozzle boom. Treatments were applied over 4 ft wide beds and to plots 10 ft long. Each treatment was replicated 4 times.

Alion (Indaziflam, Bayer) is a recently developed new herbicide with some potential uses in nursery production, but in this study seriously damaged newly transplanted 1-0 hemlocks (*Tsuga heterophylla*). Mission herbicide (flazasulfuron, ISK) provided exceptional full season control of cottonwoods with very little injury to the transplants (Table 3). Other important species controlled included marestail (*Conyza canadensis*) and northern willowherb (*Epilobium ciliatum*). Recent research in Christmas trees also indicates good tolerance in conifers, control of wild carrot, and suppression of horsetail (*Equisetum arvense*). Mission herbicide was recently labeled for vineyards in Oregon and should be further tested in nurseries and the registrant encouraged to expand the label.

Table 3. Herbicide effects on conifer seedlings when harvested in fall of 2012.

	Product	Herbicide(s)	Product rate	Timing	Tree shoot wt	Root wt.	Tree ht.	Weed control when trees were pulled in November, 2012			
								Marestail (*Conyza*)	Cotton-wood	N. willow-herb	Composite rating
			#/A		*g*	*g*	*cm*	----------*% control*---------			
1	Alion	indaziflam	5 oz	PES[a]	61	56	33.7	100	100	100	100
2	Callisto (1 app)	mesotrione	6 oz	PES	108	68	32.2	100	83	73	76
3	Callisto (2 app)	mesotrione	6 oz	PES/POST	75	59	28.0	100	75	95	81
4	Callisto (2 app)	mesotrione	8 oz	PES/	79	51	30.0	100	93	73	65
5	Alion	indaziflam	2.5 oz	PES	62	34	35.3	88	88	90	85
6	Dimension	dithiopyr	0.47 lb	PES	116	66	37.2	85	50	48	54
7	Mission	flazasulfuron	2 oz	PES	156	100	37.2	100	100	94	93
8	Freehand	pendimethalin+ dimethenamid-P	200 lbs	PES	45	25	28.2	98	95	91	84
9	Gallery	isoxaben	11 oz	PES	116	36	37.6	71	0	38	53
10	Goal Tender	oxyfluorfen	1 pt	PES	130	71	38.4	88	25	86	57
11	Treevix	saflufenacil	1 oz	PES	95	41	33.0	88	23	20	34
12	Snapshot	trifluralin + isoxaben	100 lbs	PES	149	75	41.0	85	40	90	58
13	SureGuard	flumioxazin	8 oz	PES	119	66	42.7	88	88	100	85
14	V10233	flumioxazin + pyroxsulam	8 oz	PES	157	99	40.6	100	100	89	90
15	Raptor	imazamox	5 fl oz	POST	72	53	23.6	8	100	90	53
16	Starane Ultra	fluroxypyr	1/3pt	POST	76	40	32.8	68	83	20	45
17	Unweeded	-	-	-	91	32	34.0	-	-	-	-
18	Weeded	-	-	-	154	65	39.7	49	30	55	36
19	Mission Goal Tender	flazasulfuron+ oxyfluorfen	2 oz 1 pt	PES PES	158	94	38.4	97	100	96	96
	FPLSD (0.05)				*46*	*35*	*8.1*	*37*	*33*	*34*	*28*

[a] PES; preemergence surface

June 2012, Aurora

The second site was initiated in four ornamental tree plantings. The objective was to determine whether improvements could be made, using tankmixes of common or potential products, to extend weed control without jeopardizing crop safety. Treatments were applied on June 6 shortly after the sites had been cultivated and hand hoed to remove all weeds. Treatments were applied with a back pack CO_2 powered sprayer using a single XR-8002 nozzle on both sides of the tree row. One row received one treatment in each of the four plantings of *Acer rubrum* ‘October Glory’, *Acer rubrum* ‘Redpointe’, *Pyrus calleryana* 'Chanticleer' and *Crataegus viridis* 'Winter King'. Plots were 30 to 50 ft in length (depending on site) with an untreated check plot at the ends of the row as a reference for weed control. Rainfall of 0.4 in was recorded the day following application.

Crop injury was noted on the July 6 evaluation, one month after treatment, primarily in the Alion treatments (Table 4). There was slight evidence that herbicide injury was greater overall in the *Pyrus* and *Crataegus* spp. The combination of Gallery and Pendulum Aquacap provided nearly 100% control 7 weeks after application. Gallery + Surflan, Alion, and Matrix also performed well. Matrix is sulfonylurea herbicide that is primarily used preemergence, with a very low use rate and low environmental impact. It controls common mallow seedlings, marestail, and quackgrass very well and may have an important fit in systems where these weeds have become prevalent.

Table 4. Response of ornamental trees to herbicides.

	Treatment		Rate	Phyto	Weed control	Phyto
				7/6/2012	8/30/2012	8/30/2012
			#/A	*0-10 (10 = dead)*	*%*	*0-10 (10 = dead)*
1	Gallery	isoxaben	1 lb	0.4	91	0
2	Gallery	isoxaben	1 lb	1.1	96	0
	Surflan	oryzalin	4 qts	0.8		
3	Gallery	isoxaben	1 lb	1.1	99	0
	Pendulum Aquacap	pendimethalin	4.2 qts	0.4		
4	Gallery	isoxaben	1 lb	1.9	93	0
	Dimension	dithiopyr	24 oz	0.5		
5	Dimension	dithiopyr	24 oz	0.4	91	0
6	Alion	indaziflam	5 oz	1.1	96	0
7	Matrix	rimsulfuron	4 oz	0.8	95	0
	FPLSD (0.05)			*1.2*	*ns*	*ns*
1	*Acer rubrum* ‘October Glory’			0.3	-	0
2	*Acer rubrum* ‘Redpointe’			0.9	-	0
3	*Crataegus viridis* 'Winter King'			1.3	-	0
4	*Pyrus calleryana* 'Chanticleer'			1.1	-	0
	FPLSD (0.05)			*0.9*		*ns*

August 2012, Dayton

A third site was established on August 23 at 2 sites near Dayton that included *Syringa reticulata* 'Ivory Silk' (approx. 1.5 to 2 ft tall), *Carpinus betulus* 'Fastigiata' (3 to 6 ft tall), and four varieties of hydrangea (approx. 12-16 in tall, see Table 6 for varieties). Treatments applied included Gallery, Dimension, Pendulum Aquacap, Alion, and Mission herbicides. Herbicides were applied with a CO_2 back-pack sprayer @ 30 psi using Tee-Jet 8002 VS nozzles. Herbicides were directed on both sides of the row in *C. betulus* and *S. reticulata*, but applied over the top of hydrangea plants.

Site 1 (*C. betulus and S. reticulata*). Ratings 2 weeks after application indicated no injury from the herbicides to *C. betulus*, but a phytotoxicity rating of 3 (scale of 0-10) on *S. reticulata* that was caused by Alion herbicide. Subsequent evaluation in November 7 did not reveal any damage to the same species. Weed control was best with Alion and Mission, but Alion also suppressed emergence of a wheat cover crop planted between the rows in mid-September.

Table 5. Tolerance of *C. betulus and S. reticulata* to a late summer herbicide applications.

	Product	herbicide	Rate	Phytotoxicity	Stunting	Weed control	Cover crop suppression
				6-Sep	7-Nov	7-Nov	7-Nov
			#/A	*0-10*	*%*	*%*	*%*
C. betulus							
1	Gallery	isoxaben	1 lb	0	0	50	0
2	Dimension	dithiopyr	0.75 lbs	0	0	70	0
3	Pendulum Aquacap	pendimethalin	4.2 qts	0	0	50	0
4	Alion	indaziflam	5 oz	0	0	100	90
5	Mission	flazasulfuron	2 oz	0	0	100	0
6	Check nontreated	-		0	0	0	0
S. reticulata							
1	Gallery	isoxaben	1 lb	0	0	50	-
2	Dimension	dithiopyr	0.75 lbs	0	0	90	-
3	Pendulum Aquacap	pendimethalin	4.2 qts	0	0	100	-
4	Alion	indaziflam	5 oz	3	0	100	-
5	Mission	flazasulfuron	2 oz	0	0	100	-
6	Check nontreated	-		0	0	0	-

Site 2 (*Hydrangea spp.*, see Table 6 below for species and varieties). Ratings 2 weeks after application indicated significant injury from herbicides to hydrangea with the greatest injury caused by Alion and the grower applied treatment of Ronstar. Gallery and Pendulum Aqua caused the least amount of damage and provided good weed control. There also appeared to be a difference in tolerance of the four species to herbicides in general, with *H. quercifolia* being the most tolerant of the four. Weed control was best with Alion but also caused the most injury to the crop. Alion seldom has contact herbicidal injury, but hydrangea appeared overly sensitive compared to observations on other crops over the last 4 years.

Table 6. Tolerance of 4 varieties of hydrangea to late summer herbicide applications.

Variety/Product		Herbicide	Rate	Phyto	Stunting	Weed control	Phyto
				6-Sept	6-Sept	6-Sept	7-Nov
			#/A	*0-10*	*%*	*%*	*0-10*
Herbicide							
1	Gallery	isoxaben	1 lb	1.3	28	81	2.0
2	Dimension	dithiopyr	0.75 lbs	1.7	23	70	3.8
3	Pendulum Aqua	pendimethalin	4.2 qts	1.3	18	85	1.3
4	Alion	indaziflam	5 oz	3.7	40	98	4.8
5	Nontreated			0.7	5	0	1.5
6	Grower check	oxadiazon	-	2.0	33	60	-
	FPLSD (0.05)			*2.3*	*33*	*24*	*2.7*
Variety/Species							
1	*Hydrangea arborescens* 'Annabelle'			2.2	24	-	2.8
2	*Hydrangea quercifolia*			0	18	-	1.2
3	*Hydrangea paniculata* 'Grandiflora'			-	30	-	2.8
4	*Hydrangea macrophylla* 'Nikko Blue'			3.8	40	-	2.6
	FPLSD (0.05)			*1.8*	*ns*	-	*ns*

September 2012, Wilsonville

A fourth site was established in a boxwood (*Buxus sempervirens*, several varieties from cuttings) and blue spruce (*Picea pungens*, several varieties, grafted*)* nursery near Wilsonville. Treatments were applied on Sept 14, 2012 to plots 15 x 4ft and each treatment replicated 2 times in each of the two species, for a total of 4 replicated plots per treatments. Treatments were applied with a CO_2 back-pack sprayer @ 20 psi with a two nozzle boom (18" spacing) using Tee-Jet 8002 VS nozzles. Herbicides were incorporated with standard irrigation rates.

Annual bluegrass was the primary weed species present and was controlled very well by Dimension and Alion, as expected (Table 7). Unexpected was the control of the annual bluegrass provided by SureGuard initially, although it dissipated quickly. Crop injury to boxwood 2 months after treatment was significant for most of the herbicides applied except Gallery and SureGuard. Only Alion caused significant injury to spruce transplants. Survival of boxwood in July, 2013 was not influenced by herbicide applied in 2012. Survival of blue spruce was only 33% in the check plot, indicating that herbicide treatments did not increase mortality. Significant weed control persisted through July 2013 for most treatments.

Table 7. Tolerance of boxwood and spruce transplants to herbicides.

	Product	herbicide	Rate	Phyto rating	Annual bluegrass control	Crop injury	Annual bluegrass control	Crop injury	Crop survival	Weed control
			#/A	*10/2/12*	*10/2/12*	*11/7/12*	*11/7/12*	*7/24/13*	*7/24/13*	*7/24/13*
				0-10	*%*	*%*	*%*	*%*	*%*	*%*
Boxwood										
1	Gallery	isoxaben	1 lb	0	35	0	10	13	100	35
2	Dimension	dithiopyr	0.75 lbs	0	90	25	70	15	100	99
3	Pendulum Aqua	pendimethalin	4.2 qts	0	73	50	50	0	100	94
4	Alion	indaziflam	5 oz	1.5	99	50	100	35	93	98
5	Surflan	oryzalin	2 lb	0	84	65	65	15	100	60
6	Barricade/ Factor	prodiamine	48 oz	0	65	50	50	25	100	99
7	SureGuard	flumioxazin	10 oz	3.0	73	15	35	25	100	40
8	Check			-	-	5	5	15	100	-
Spruce										
1	Gallery	isoxaben	1 lb	0	85	10	50	70	34	94
2	Dimension	dithiopyr	0.75 lbs	0	83	0	65	45	59	100
3	Pendulum Aqua	pendimethalin	4.2 qts	0	88	20	70	60	50	100
4	Alion	indaziflam	5 oz	0	99	45	95	70	52	100
5	Surflan	oryzalin	2 lb	0	90	15	60	50	62	99
6	Barricade/ Factor	prodiamine	48 oz	0	73	0	50	38	47	100
7	SureGuard	flumioxazin	10 oz	0	63	0	20	70	47	94
8	Check			0	0	0	0	80	33	-
	FPLSD (0.05)			*0*	*30*	*41*	*28*	*30*	*16*	*56*

3. Preliminary screen for herbicide resistance

Seeds of marestail were collected from sites from N to S in the Willamette Valley and several sites in the Columbia Basin. Seeds from plants known to be susceptible to glyphosate from Davis CA were used in the experiment also. Seeds were planted in 4 in pots on Feb 11 and thinned to 4 plants per plot on Feb 28. Glyphosate was applied at 2 rates when plants had 6-8 leaves. Each treatment was replicated 4 times. At one week after treatment there appeared to be differences among the sites in tolerance to glyphosate but by 2 weeks after treatment symptoms across treatments were similar. Eventually all plants died. Differences in response to glyphosate may have been due to differences in growth stage at application as there were very visible differences among the biotypes collected both in plant form and vigor. Overall, there appeared to be very little evidence that horseweed is strongly resistant to glyphosate. However, in the first test run of this trial in December 2012 a very low application rate (probably < 0.1 lb ae/A) of glyphosate was applied in error. Several individual plants completely survived the low application rate and there appeared to be differences among sites, even though the data were highly variable and statistically we could not sort out differences among treatments. Missing from the December trial was the known susceptible from Davis CA.

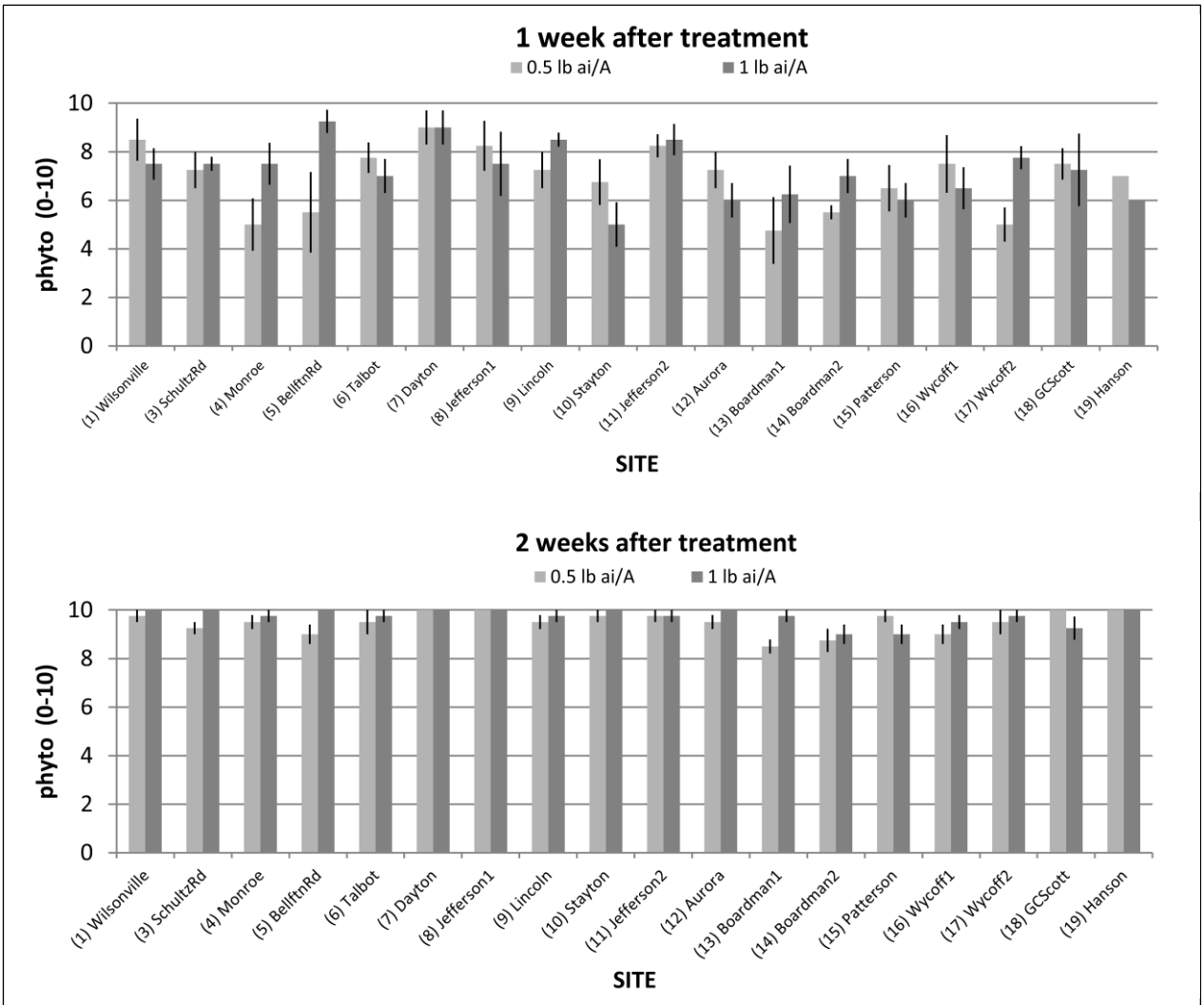

Figure 1. Marestail tolerance to 0.5 and 1 lb glyphosate at 1 and 2 weeks after treatment. Seed from site 19 was collected in CA and was included as the 'known glyphosate susceptible' reference. Seed provided by Brad Hanson, UC Davis.

Annual bluegrass plants were collected from several fields and can-yards near St. Paul in October 2012. Plants were grown in the greenhouse and seeds collected in February, 2013. A preliminary screen for diuron resistance was made but there was little evidence that the collections were resistant.

Conclusions

Herbicides are the main tool available in the fight against weeds for managers producing field grown plants. A high level of control is demanded throughout the growing season, and this level is not fully determined by the risk of competition or contamination of product. Aesthetics also is valued, particularly when interested buyers view fields during the production season. Major weed control efforts precede the Farwest show held annually in late August. The threshold of weed tolerance is set so low that it is difficult to imagine what other practices or tools could possibly improve current weed control efforts compared to the herbicides currently available, cultivation, and hand hoeing, particularly in light of the relatively low cost per unit of control for herbicides. It is extremely important under these constraints that every available practice be brought to bear on weeds in these systems, including prevention of weeds producing seed (both within and adjacent to the crop when possible), and minimizing seed and propagule movement on equipment. Even then it is expected that hand hoeing will be essential to successful production.

Product screening should continue. Despite the fact that only 1 new herbicide mode of action has been discovered over the last 2 decades, there are a number of new products with unique control spectrums that should be evaluated. Screening efforts also will improve the understanding of what weeds herbicides will or will not control, and under what conditions herbicides will perform best in the PNW, and in particular the Willamette Valley. This information will in turn allow managers to tweak application rates, adjust timings, and in some cases engineer tank mixes that better address the weeds that current practices miss. The outcome of these efforts would be less herbicide applied to fewer acres and ultimately lower cost. Unfortunately, this is not a hit and miss proposition, but one that will require a sustained effort over time. Given the budget constraints borne by both public and private investigators at the moment, it is unclear from where the resource would emerge to initiate this effort.

Alion herbicide is a recent release of Bayer with a unique mode of action that provides extremely broad-spectrum preemergence control and should be evaluated for use in field grown nursery stock. As indicated by this study, there may be significant differences in tolerance of crop and even varieties within crops.

Mission herbicide also showed promise in the study, even though it was not screened at all sites. Mission controls a number of difficult species, including wild carrot, willow herb, and annual ryegrass and can be used both as a pre- and postemergent herbicide. Conifers appear to be extremely tolerant, and there was evidence that broadleaved crop tolerance might be acceptable if using directed applications. Cotton wood control was exceptional.

There are reduced-rate and non-herbicidal strategies that could be considered, but most do not come with a lower price tag. Equipment is currently available that allows selective and non-selective postemergent herbicides to be targeted only where weeds are present. Producers will be reluctant to leave preemergence herbicides off the table, however, and it is unlikely that the cost of this equipment and its operation will fall short of hand hoeing. The main obstacle to use of many of these tools is the extreme diversity of plant types, sizes, and arrangements that equipment must to adjust to. Such is the case with propane flaming, which could be useful in some systems where directed application can be made under the canopy. In-row cultivation would be possible in some situations with guided implements, but damage to short and recently budded plants may be an obstacle. Use of drip irrigation that also delivers fertilizer might slow weed emergence and growth between the rows, but the cost of removing weeds in this zone is very reasonable with cultivation.

Resistance of marestail to glyphosate is unlikely, and probably does not explain the burgeoning populations of this weed throughout the Willamette valley. One decade ago, it was difficult to find marestail; now it can be found throughout the valley, growing in continuous stands along roadways and

dominating production sites. Even though annual bluegrass did not appear to be resistant to important herbicides at 2 sites, it is likely that this weed is resistant to several classes of herbicides in the Willamette valley, and care should be taken when selecting sites.

Figure 2. Hemlock seedlings, Canby, Nov. 2012.

Figure 3. *A. rubrum*, Aurora, June 2012.

Figure 4. *Hydrangea spp*, Dayton, Sept. 2012.

Figure 5. Lilac and hornbeam, Dayton, Nov. 2012.

Figure 6. Annual bluegrass in untreated plots in boxwood and spruce, Nov. 2012.

Figure 7. Screening for glyphosate resistance in marestail Mar. 2013