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Control of Northern Willowherb in Nursery Containers[1]

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Abstract

Four experiments were conducted to determine the effectiveness of granular and sprayed preemergence herbicides for controlling northern willowherb (*Epilobium ciliatum* Rafin) in container crops. Eleven granular herbicides representing various combination of pendimethalin, prodiamine, oryzalin, oxyfluorfen, oxadiazon, napropamide, isoxaben, trifluralin, and flumioxazin were evaluated, as well as sprayed Surflan AS (oryzalin), Devrinol 50-DF (napropamide), Barricade 4FL (prodiamine), and Gallery 75DF (isoxaben). Herbicides were applied to recently filled containers and irrigated with overhead sprinklers. Weed numbers were counted in each pot and weed shoot dry weight was measured at the conclusion of each study. Ronstar G (oxadiazon) at 4.48 kg ai/ha (4 lb ai/A) consistently provided the most effective control among all herbicides. Other granular herbicides containing oxadiazon were also effective. Surflan and Devrinol did not consistently reduce weed numbers as effectively as Ronstar G, however they did reduce subsequent growth of northern willowherb seedlings that were able to successfully establish. Gallery did not provide any control alone nor did it improve control when tank mixed with other products.

Index words: *Epilobium ciliatum*, preemergence herbicide, weeds.

Herbicides used in this study: Gallery 75DF (isoxaben), *N*-[3-(1-ethyl-1-methylpropyl)-5-isoxazolyl]-2,6-dimethoxybenzamide; Surflan AS (oryzalin), 4-(dipropylamino)-3,5-dinitrobenzenesulfonamide; Devrinol 50-DF (napropamide), *N*,*N*-diethyl-2-(1-naphthalenyloxy)propanamide; Barricade 4FL (prodiamine), 2,4 dinitro-N^3,N^3-dipropyl-6-(trifluoromethyl)-1,3-benzenediamine; Ornamental Herbicide II (OH2, pendimethalin + oxyfluorfen), *N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine + 2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene; Rout (oryzalin + oxyfluorfen), 4-(dipropylamino)-3,5-dinitrobenzenesulfonamide + 2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene; Snapshot 2.5TG (isoxaben + trifluralin), *N*-[3-(1-ethyl-1-methylpropyl)-5-isoxazolyl]-2,6-dimethoxybenzamide + 2,6-dinitro-*N*,*N*-dipropyl-4-(trifluoromethyl)benzenamine; Pendulum 2G (pendimethalin); Ronstar G (oxadiazon), 3-[2,4-dichloro-5-(1-methylethoxy)phenyl]-5-(1,1-dimethylethyl)-1,3,4-oxadiazol-2-(3*H*)-one; BroadStar (flumioxazin), 2-[7-fluoro-3,4-dihydro-3-oxo-4-(2-propynyl)-2*H*-1,4-benzoxazin-6-yl]-4,5,6,7-tetrahydro-1*H*-isoindole-1,3(2*H*)-dione; Pre Pair (napropamide+oxadiazon); Kansel+ (oxadiazon+pendimethalin); Regal O-O (oxadiazon+oxyfluorfen); RegalKade (prodiamine); RegalStar (oxadiazon+prodiamine).

Significance to the Nursery Industry

Northern willowherb is one of the most common weeds in west coast nurseries, and is becoming increasingly problematic in east coast nurseries. Seeds of northern willowherb are wind-disseminated so sanitation is crucial for preventing infestations. Preemergence herbicides can be effective. Data herein demonstrate that Ronstar G (oxadiazon) at the maximum labeled rate of 4.48 kg ai/ha (4 lb ai/A) consistently provided effective control in reducing northern willowherb number and growth. Spray-applied Surflan AS (oryzalin) or Devrinol 50-DF (napropamide) at 4.48 or 6.72 kg ai/ha (4 or 6 lb ai/A), respectively, are not overly effective in suppressing establishment of northern willowherb seedlings; however, seedlings that do establish generally remained stunted with little or no appreciable growth. Relying solely on Ronstar G might lead to a weed shift from northern willowherb to another species more tolerant of that compound. A combination of sanitation and herbicide rotation should be used to control this and other weed species in container production systems.

Introduction

Northern willowherb (*Epilobium ciliatum* Rafin, syn. *E. adenocaulon* Hauss.) is a perennial in the family Onagraceae. It is native to North America and can be found from New Brunswick to Alaska and south to New Mexico and North Carolina (18), but has also been documented in Australia, New Zealand (13), China, Japan, and Korea (7). It is one of the most prevalent weed species in west coast container nurseries and is becoming increasingly problematic in cooler regions along the east coast (19). It has been widely documented as a weed of tree nurseries, orchards, and other crops throughout Europe (4, 5, 8, 9). *E. ciliatum* is wrongly, but commonly, referred to as fireweed by many west coast nurserymen. Northern willowherb is also known by the common names hairy willowherb, slender willowherb, or fringed willowherb depending on the region where it is found.

A single plant can produce up to 60,000 seeds per plant per season (14). Seeds are attached to a tuft of hair, which aids in wind dispersal allowing for widespread seed dissemination in container nurseries. Northern willowherb germinates in dry to water logged soils, and is particularly well suited for establishing in dry soils compared to other species in the same genera (17). Alternating cycles of wet and dry typical of the substrate surface in many container nurseries would not deter this species from establishing. Northern willowherb seeds germinate readily in full sun (100%) or darkness (84%) (12), making them well adapted to germination in containers with little or complete cover from crop canopies. Furthermore, northern willowherb grows well in shade with little or no change in biomass (17). Shade will reduce subsequent seed capsule production, but this may be of little consequence to a crop already infested. Seeds can germinate over a range of temperatures from 4 to 36C (39 to 97F), although germination is reduced as temperatures approach 30C (86F) (12, 17). This allows germination to occur throughout the spring and summer growing season in northern climates, and virtually year-round in protected container

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crops. It also explains why its spread has been primarily limited to cooler summer climates typical of the Pacific Northwest and northeast United States. Northern willowherb seed that mature during the summer have no dormancy (6, 12). Germination of seed from recently ripened seed pods occurred within four days of sowing (personal observation). Plants can flower in 5 to 6 weeks and then produce mature seed 4 weeks later (17). This species only requires 9 to 10 weeks for seeds to germinate, mature, and produce another generation of seeds. This allows multiple generations during a single growing season in most nursery producing regions. Northern willowherb also reproduces vegetatively. The over wintering rosette contains buds which detach easily from the parent plant and can spread through tillage or cultivation (18). This method of reproduction can hamper handweeding, although in terms of reproduction and spread it is of little importance in container nurseries.

This species demonstrates strong apical dominance (11) growing rapidly up to 1.5 m (4.9 ft) tall; taller than all other common container weeds in Oregon and many crops common to container production (1). Rapid growth allows this weed to out-compete many smaller container shrubs and herbaceous perennials for light. Irwin and Aarssen (15) documented that the benefit of apical dominance in northern willowherb (in terms of capsule production) was most evident when competing with plants growing under high nutrient levels where competition for light is expected to be most intense. These conditions are characteristic of virtually all container nurseries.

Northern willowherb growing in non-crop areas can be controlled postemergence with glyphosate (3). Some biotypes are resistant to paraquat (9). Even complete sanitation in and around the nursery cannot exclude all northern willowherb seed due to its wind-dispersal. Preventive control with preemergence herbicides or some type of physical barrier over the container substrate (mulches, weed disks, etc.) is prudent.

Research in orchard systems in the United Kingdom reported that oxyfluorfen and bifenox prevented seedling emergence (3). Bifenox is not labeled for nursery production in the United States, but oxyfluorfen is labeled and is used both as a stand-alone spray in container-grown conifers and as a component of several granular herbicides. Napropamide and pendimethalin at 2 and 1.3 kg ai/ha (1.8 and 1.2 lb ai/A), respectively, were also evaluated in this study and found to be ineffective. However, the Europeans tested rates lower than the maximum labeled rates in the U.S. for container crops (6.72 and 4.5 kg ai/ha (6 and 4 lb ai/A), respectively). A later, more exhaustive study demonstrated effective control with the following sprayed herbicides: oxyfluorfen (0.25 to 4 kg ai/ha (0.2 to 3.6 lb ai/A)), oxadiazon (0.25 to 4 kg ai/ha), napropamide (6 kg ai/ha (5.6 lb ai/A)), and pendimethalin (4 kg ai/ha) (2). Dixon and Clay (10) evaluated napropamide, isoxaben, and pendimethalin (among many other non-labeled products) at rates that were approximately 10% of those typically used in the U.S. They reported excellent control with all products; however, they also indicated very high temperatures in their greenhouse experiments may have reduced weed growth across all treatments. While these data provide useful information, these trials were all conducted on field soils, conducted with European biotypes of northern willowherb, and with herbicides rates much lower than those used in the United States. The objective of these experiments was to identify effective preemergence herbicides currently labeled in the U.S. for control of northern willowherb in nursery containers.

Materials and Methods

All experiments were conducted at the Oregon State University North Willamette Research and Extension Center in Aurora, OR. Northern willowherb seeds were collected from local populations the previous summer and stored at room temperature in a plastic container. Northern willowherb was the only plant studied in these experiments.

Experiment 1. On May 6, 2004, #1 containers were filled with 100% Douglas fir (*Pseudotsuga menziesii* (Mirbel) Franco) bark amended with 9.5 kg/m^3 (16 lbs/yd^3) Osmocote 18–6–12 (18N–2.6P–10.3K, Scott's Co., Marysville, OH) and 0.9 kg/m^3 (1.5 lbs/yd^3) Micromax micronutrients (Scott's Co.). Granular herbicides (Table 1) were applied May 17 with a handheld shaker. All herbicides were applied at the highest labeled rate. A non-treated control group was also maintained. Containers were irrigated immediately after herbicide application with 1.2 cm (0.5 in) water and thereafter with the same volume split in two equal applications per day. Twenty northern willowherb seeds were applied to each container May 18. There were eight single pot replications per treatment

Table 1. Preemergence northern willowherb (*Epilobium ciliatum*) control with granular herbicides.

Herbicide	Common name	Rate (kg ai/ha)	Number[z] 3 WAT[y]	SDW (g) 8 WAT
BroadStar	flumioxazin	0.42	2.9cd[x]	10.2bcd
Kansel+	oxadiazon+pendimethalin	3.64	7.6ab	18.4ab
OH2	oxyfluorfen+pendimethalin	3.36	2.0de	14.5abc
Regal O-O	oxyfluorfen+oxadiazon	3.36	4.8bcd	13.9abc
RegalStar	oxadiazon+prodiamine	2.69	1.6de	7.8cd
RegalKade	prodiamine	1.68	6.3abc	12.0bc
Ronstar G	oxadiazon	4.48	0.1e	3.0d
Rout	oxyfluorfen+oryzalin	3.36	2.4d	9.6cd
Snapshot 2.5TG	isoxaben+trifluralin	5.6	6.9ab	12.7abc
Control			9.8a	20.8a

[z]Number of northern willowherb germinated in containers. Data were square root transformed prior to analysis, but actual data are presented.

[y]Weeks after treatment.

[x]Means with the same letter within a column are not different according to Fisher's Protected LSD ($\alpha = 0.05$).

arranged in a completely randomized design. Data collected included northern willowherb number 3 weeks after treatment (WAT) and shoot dry weight (SDW) 8 WAT.

Experiment 2. The objective of this experiment was to determine granular herbicide efficacy immediately after herbicide application and 30 days after application. The experiment was conducted similarly to Expt. 1 with the following exceptions. On July 14, 2004, #1 containers were filled with 100% Douglas fir bark amended with 9.5 kg/m^3 Osmocote 18–6–12, 0.9 kg/m^3 Micromax micronutrients, and 1.8 kg/m^3 (3 lbs/yd^3) dolomitic lime. Herbicides (Table 2) were applied July 16 to 12 containers per treatment. Seeds were applied to six of the 12 containers immediately after herbicide application (0 WAT), then to six different containers per treatment at 4 WAT. Data collected included northern willowherb number and height 8 WAT, and number and SDW 12 WAT.

Experiment 3. The objective of Expt. 3 was to compare the efficacy of granular preemergence herbicides and commonly used sprayed preemergence herbicides. On July 28, 2004, #1 containers were filled with the same substrate used in Expt. 2. Herbicides (Table 3) were applied to all containers July 30. Sprayed herbicides were applied with a CO_2 backpack sprayer equipped with a three-nozzle boom containing 8004 flat fan nozzles. The sprayer was set at 2.46 kg/cm^2 (35 psi) and calibrated to deliver 467 liters/ha (50 gal/A). Granular herbicides were applied with a handheld shaker. Herbicides were applied to 12 containers per treatment. Seed were applied 0 and 4 WAT similarly to Expt. 2. All containers were arranged in completely randomized design. Among containers in which seeds were applied 0 WAT, data collected included weed number 1, 4, and 8 WAT, weed height 4 WAT, and weed SDW 8 WAT. Among containers in which seeds were applied 4 WAT, data collected included weed number 8 and 12 WAT and weed SDW 12 WAT.

Experiment 4. Expt. 4 was conducted similarly to Expt. 3 with the following exceptions. Containers were filled July 26, 2005. The same herbicides in Expt. 3 were applied with the addition of Snapshot at 5.6 kg ai/ha (5 lb ai/A). Seeds were applied 0 and 4 WAT. Among containers in which seeds were applied 0 WAT, data collected included weed number 3, 5, and 10 WAT, and weed SDW 12 WAT. Among containers in which seeds were applied 4 WAT, data collected included weed number 5, 10, and 14 WAT, and SDW 16 WAT.

Results and Discussion

Experiment 1. Ronstar G, OH2, and RegalStar reduced northern willowherb numbers 3 WAT the most (Table 1). Snapshot, Kansel+ and RegalKade did not reduce weed numbers compared to non-treated controls. While OH2 reduced weed numbers 3 WAT, subsequent growth of those weeds was similar to non-treated controls by 8 WAT. Ronstar G numerically reduced weed growth the most, but was similar to Rout, BroadStar, and RegalStar. Northern willowherb control seemed to be responsive to oxadiazon rate. Ronstar G, RegalStar, and Regal O-O reduced SDW by 89, 63, and 33%, respectively, compared to non-treated controls. Ronstar G contains 2% oxadiazon resulting in 4.48 kg/ha oxadiazon; RegalStar contains 1% oxadiazon resulting in 2.24 kg/ha oxadiazon; Regal O-O contains 1% oxadiazon and thus only 1.12 kg oxadiazon/ha was applied. Kansel+ applications result in the same oxadiazon rates as RegalStar, however, control was poor with this product. Kansel+ is formulated on a fertilizer carrier. This carrier was coarse with a wide range of particle sizes making uniform application difficult (personal observation).

Experiment 2. Among containers in which seeds were applied 0 WAT, all herbicides reduced weed numbers and height compared to non-treated controls 8 WAT (Table 2). Ronstar G, PrePair, and BroadStar provided 100% northern willowherb control, although other treatments provided statistically similar levels of control. By 12 WAT weed numbers were higher. No treatment reduced weed numbers compared to non-treated controls. Weed numbers in non-treated control pots were low because only a few dominant plants out-competed the others, while in herbicide treated containers stunted seedlings were small enough to coexist with each other. Only Snapshot failed to reduce weed growth in containers compared to non-treated controls. All other herbicide reduced northern willowherb growth. Despite statistically similar SDW among treated containers, BroadStar, PrePair, and Ronstar G resulted in near zero weed growth. While weeds germinated in all these treatments, they were so stunted and small that the weight of northern willowherb averaged across the replications was < 0.05 g (thus rounded to 0.0 g). Considering both reduction in weed number and SDW, Ronstar G and PrePair provided superior control. PrePair also contains 2% oxadiazon and at its application rate resulted in 3.36 kg/ha (3 lb/A) oxadiazon. Similar to Expt. 1, oxadiazon at higher application rates provides excellent control.

Among containers in which seeds were applied 4 WAT, Ronstar G and PrePair again provided complete control. At 8 WAT, considering both weed number and height, Kansel+, Snapshot, and RegalKade resulted in poor northern willowherb control. At 12 WAT, no herbicide reduced weed numbers compared to non-treated controls. Kansel+ and Snapshot resulted in greater weed SDW than non-treated controls while Ronstar G and PrePair were the only treatments to reduce weed SDW. Containers treated with Ronstar G and PrePair had numerically the fewest weeds per container and the mass of those weeds was so small that the average SDW was less than 0.05 g.

Experiment 3. Among containers in which seeds were applied immediately after herbicide application, Ronstar G reduced weed numbers in containers through 4 WAT more than all other herbicides (Table 3). Among granular herbicides, Ronstar G reduced weed numbers lower than Rout and RegalKade throughout the experiment, both of which did not reduce weed numbers compared to non-treated controls. This concurs with Expts. 1 and 2 in which Ronstar G consistently reduced weed number and shoot dry weight compared to RegalKade and Rout, although differences weren't always significant.

At 1 WAT and throughout the experiment, adding Gallery to Devrinol, Barricade, or Surflan did not improve control over any of those herbicides alone (Table 3). Furthermore, Gallery alone did not reduce weed numbers compared to non-treated controls. Devrinol with or without Gallery did not reduce weed numbers compared to non-treated controls; however, weed heights in these containers were small. Surflan treatments reduced weed numbers compared to non-treated controls, although weed numbers were still relatively high.

Table 2. Northern willowherb control with granular preemergence herbicides when seeds are applied 0 or 4 weeks after herbicide application.

			Seeds applied 0 WAT				Seeds applied 4 WAT			
Herbicide	Common name	Rate (kg ai/ha)	Number[y] 8 WAT	Height (cm) 8 WAT	Number 12 WAT	SDW (g) 12 WAT	Number 8 WAT	Height (cm) 8 WAT	Number 12 WAT	SDW (g) 12 WAT
BroadStar	flumioxazin	0.42	0.0c[x]	0.0c	10.5ab	0.0c	1.0bc	0.3b	15.8a	0.9cd
Kansel+	oxadiazon+pendimethalin	3.64	0.5c	5.7bc	14.7a	7.5bc	1.5bc	6.0a	9.0abc	11.1a
OH2	oxyfluorfen+pendimethalin	3.36	0.3c	3.8bc	12.3ab	4.2c	1.7bc	0.3b	9.2abc	0.3cd
Pendulum 2G	pendimethalin	4.48	0.8bc	0.3c	12.2ab	0.4c	2.3b	0.7b	12.3abc	0.7cd
PrePair	napropamide+oxadiazon	10.08	0.0c	0.0c	0.2d	0.0c	0.0c	0.0b	3.5d	0.0d
Regal O-O	oxyfluorfen+oxadiazon	3.36	0.3c	0.7c	9.7ab	1.3c	0.5c	1.2b	9.7abc	1.4cd
RegalStar	oxadiazon+prodiamine	2.69	0.3c	5.7bc	8.2abc	8.2bc	0.8bc	0.2b	13.5ab	0.2cd
RegalKade	prodiamine	1.68	1.0bc	7.0bc	9.3ab	6.7bc	7.0a	1.0b	7.7abcd	2.3cd
Ronstar G	oxadiazon	4.48	0.0c	0.0c	1.7cd	0.0c	0.0c	0.0b	5.3cd	0.0d
Rout	oxyfluorfen+oryzalin	3.36	0.2c	2.0bc	9.2ab	4.5c	1.0bc	0.2b	13.0abc	0.4cd
Snapshot 2.5TG	isoxaben+trifluralin	5.6	1.7b	8.9b	9.5ab	16.7ab	7.8a	4.7a	10.2abc	9.0ab
Control			2.7a	17.2a	4.0bcd	20.4a	7.0a	1.7b	5.7bcd	4.6bc

[z]Weeks after treatment.

[y]Number of northern willowherb germinated in containers. Data were square root transformed prior to analysis, but actual data are presented.

[x]Means within a column with the same letter are not different, Duncan's multiple range test ($\alpha = 0.05$).

While weeds were able to germinate in Surflan and Devrinol treatments, they did not grow thereafter as indicated by weed heights. By 8 WAT, Ronstar G, Surflan, and Barricade + Gallery reduced weed numbers most effectively. Across all treatments, weed numbers decreased from 4 to 8 WAT. This could be because stunted weeds in the Surflan and Devrinol treatments never grew and eventually died. Devrinol treatments did not reduce weed numbers, however, SDW data again show that established seedlings were not able to grow far beyond the cotyledon stage. Devrinol alone and Devrinol + Gallery reduced SDW by 91 and 83%, respectively. Bailey et al. (3) had similar results with napropamide (Devrinol) in which they reported that the herbicide resulted in similar (although numerically greater) weed numbers than non-treated controls but that vigor of those weeds was reduced to 76% compared to non-treated controls. Surflan and Surflan + Gallery reduced weed numbers and SDW by 97 and 100%, respectively. While there were weeds in the Surflan + Gallery treated pots, these weeds were so small that average SDW rounded to 0.0 g.

Among containers in which seeds were applied 4 WAT, no sprayed herbicides reduced weed numbers throughout the experiment compared to non-treated controls. However, all sprayed treatments except for Gallery alone reduced weed SDW. Surflan provided effective preemergence northern willowherb control in terms of growth reduction. Rout also

Table 3. Preemergence northern willowherb (*Epilobium ciliatum*) control with granular and sprayed preemergence herbicides.

			Seeds applied 0 WAT[z]					Seeds applied 4 WAT		
Herbicide	Common name	Rate (kg ai/ha)	Number[y] 1 WAT	Number 4 WAT	Height (cm) 4 WAT	Number 8 WAT	SDW (g) 8 WAT	Number 8 WAT	Number 12 WAT	SDW (g) 12 WAT
Granular products										
RegalKade	prodiamine	1.68	10.3ab[x]	10.3bcd	7.9bc	6.5abc	14.3a	8.8ab	7.7ab	1.5abc
Ronstar G	oxadiazon	4.48	1.7d	2.2e	2.2de	1.2d	3.5cd	1.8c	3.0c	0.2c
Rout	oxyfluorfen+oryzalin	3.36	7.3bc	9.0cd	9.2ab	5.5abc	14.2a	6.5b	5.5b	0.8bc
Sprayed products										
Devrinol + Gallery	napropamide + isoxaben	6.72 + 1.12	8.7ab	11.5abc	1.5de	6.3abc	2.6d	10.2ab	8.7ab	1.0bc
Barricade + Gallery	prodiamine + isoxaben	1.68 + 1.12	8.2bc	8.5cd	4.7cd	3.5bcd	7.6bc	10.0ab	6.8ab	0.8bc
Surflan + Gallery	oryzalin + isoxaben	4.48 + 1.12	4.2c	6.7d	0.0e	2.5cd	0.0d	12.8a	7.8ab	0.6c
Devrinol	napropamide	6.72	10.5ab	13.3ab	0.8e	7.0ab	1.4d	13.3a	10.0a	0.9bc
Barricade	prodiamine	1.68	10.0ab	9.2cd	6.2bc	5.7abc	11.0ab	11.5a	7.2ab	1.2bc
Surflan	oryzalin	4.48	6.0bc	8.0cd	0.2e	2.8cd	0.4d	11.5a	8.3ab	1.4bc
Gallery	isoxaben	1.12	9.8ab	14.2ab	9.1ab	7.0ab	13.4a	9.8ab	8.2ab	2.1ab
Control			13.3a	15.5a	11.8a	7.7a	15.1a	11.5a	9.3a	2.8a
Contrast analysis										
RegalKade vs. Barricade			NS	NS	NS	NS	NS	NS	NS	NS
Gallery +/–			*	NS	NS	NS	NS	NS	NS	NS

[z]Weeks after treatment.

[y]Number of northern willowherb germinated in containers. Data were square root transformed prior to analysis, but actual data are presented.

[x]Means within a column with the same letter are not different, Duncan's multiple range test ($\alpha = 0.05$).

Table 4. Northern willowherb control with selected granular and sprayed preemergence herbicides.

Herbicide	Common name	Rate (kg ai/ha)	Seeded 0 WAT[z]				Seeded 4 WAT			
			Weed number[x]			SDW[y] (g)	Weed number			SDW (g)
			3 WAT	5 WAT	10 WAT	16 WAT	5 WAT	10 WAT	14 WAT	16 WAT
Granular products										
RegalKade	prodiamine	1.68	0.8abc[w]	6.4abcd	4.7bc	1.7cd	0.5cd	2.6cd	2.1d	1.3cd
Ronstar G	oxadiazon	4.48	0.0c	0.1f	0.0f	0.0e	0.0d	0.0f	0.0e	0.0d
Rout	oxyfluorfen+oryzalin	3.36	0.2bc	1.9e	0.9ef	0.5de	0.0d	1.1e	0.7e	0.0d
Snapshot 2.5TG	isoxaben+trifluralin	5.6	1.8a	9.1ab	5.4b	3.7ab	1.5ab	3.9bc	3.8bc	5.1ab
Sprayed products										
Devrinol + Gallery	napropamide + isoxaben	6.72 + 1.12	0.0c	6.1bcd	8.4a	0.1e	0.2d	4.7ab	4.7ab	1.6cd
Barricade + Gallery	prodiamine + isoxaben	1.68 + 1.12	0.2bc	5.7cd	3.4c	1.7cd	0.6cd	2.9cd	2.9cd	3.8bc
Surflan + Gallery	oryzalin + isoxaben	4.48 + 1.12	0.0c	1.7ef	1.7de	0.0e	0.1d	2.3d	2.1d	1.2cd
Devrinol	napropamide	6.72	1.0abc	2.7e	8.2a	0.1e	0.2d	5.1ab	5.0ab	2.2cd
Barricade	prodiamine	1.68	1.0abc	4.5de	3.7c	1.2de	1.2abc	2.3d	2.3d	2.5bcd
Surflan	oryzalin	4.48	0.3bc	2.8e	3.1cd	0.0e	0.2d	2.8cd	2.8cd	1.2cd
Gallery	isoxaben	1.12	0.2bc	8.2abc	8.4a	2.8bc	1.7a	4.5ab	4.8ab	6.9a
Control			1.2ab	10.1a	9.0a	4.8a	1.0bc	6.0a	5.8a	5.2ab
Contrast analysis										
RegalKade vs. Barricade			NS	NS	NS	NS	NS	NS	NS	NS
Gallery +/–			*	NS	NS	NS	NS	NS	NS	NS

[z]Weeks after treatment.

[y]Shoot dry weight.

[x]Number of northern willowherb germinated in containers. Data were square root transformed prior to analysis, but actual data are presented.

[w]Means within a column with the same letter are not different, Duncan's multiple range test ($\alpha = 0.05$).

contains oryzalin, which is the active ingredient in Surflan; however, at the labeled rates Surflan can be sprayed at 4.48 kg/ha oryzalin while Rout results in only 1.12 kg/ha oryzalin. Therefore, based solely on oryzalin rates, Rout would not be expected to control northern willowherb as well as Surflan applied at the maximum labeled rate. Ronstar G reduced weed number more than all other herbicide treatments and reduced SDW numerically lower than other treatments. Excellent control with Ronstar G is consistent with Expts. 1 and 2 and the first part of this experiment.

Experiment 4. Results were similar for Expts. 3 and 4. For brevity, only important details are discussed. Ronstar G provided the most thorough control throughout the experiment, regardless of when seeds were applied (Table 4). Contrary to results in Expt. 3, Rout also provided excellent control. Similar to Expt. 3, Gallery provided no northern willowherb control, nor did it improve control when tank-mixed with other herbicides.

In summary, northern willowherb disseminates seeds via wind and thus a few local plants have the potential to infest many containers. Where appropriate, granular Ronstar G should be applied soon after potting new plants or hand-weeding existing plants. In the four experiments described in this manuscript, Ronstar G consistently provided the most effective control in terms of reduction of northern willowherb seedlings and their subsequent growth. While Ronstar G provided excellent control of northern willowherb, the active ingredient oxadiazon is not effective on all weed species. It is particularly ineffective on weeds in the family Caryophyllaceae, most notable are pearlwort (*Sagina procumbens*) (13) and chickweed (*Stellaria media*) (4) which commonly infest nursery containers.

Surflan and Devrinol applied at the maximum labeled rates did not always reduce weed number, although these weeds were generally stunted with little growth. Surflan and Devrinol are root-inhibiting herbicides. Poor shoot growth might be interpreted as effective control from root inhibition; however, emerged weeds that were stunted might eventually grow and reproduce normally if the crop were held for sufficient amount of time. Keating et al. (16) reported that greenhouse seedlings can assume a condensed strobiloid form at the four leaf stage and remain dormant for some time (not specific) before bolting and growing with normal internode elongation. Thus, stunting at the seedling stage does not necessarily imply control.

The authors recommend that nursery producers aggressively control northern willowherb plants growing within and around the production site using a combination of hand pulling or postemergence applications of glyphosate. Ronstar G can be used in containers to prevent establishment within the crop, particularly in mid-summer when plants in surrounding areas are mature and disseminating seeds into the production site. Ronstar G can be used in rotation with other labeled preemergence herbicides.

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