Control of Orange Hawkweed (*Hieracium aurantiacum*) in Southern Alaska

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Orange hawkweed is a perennial European plant that has colonized roadsides and grasslands in south-central and southeast Alaska. This plant is forming near-monotypic stands, reducing plant diversity, and decreasing pasture productivity. A replicated greenhouse study was conducted in 2006 and repeated in 2007 to determine the efficacy of six herbicides (aminopyralid, clopyralid, picloram, picloram + chlorsulfuron, picloram + metsulfuron, and triclopyr) for orange hawkweed control. Based on results of the greenhouse trials, replicated field studies were conducted at two sites each year in 2007 and 2008 with three rates each of aminopyralid and clopyralid to determine efficacy of orange hawkweed control and impacts on nontarget native vegetation. In the field, only aminopyralid at 105 g ae ha^{-1} (0.1 lb ae ac^{-1}) and clopyralid at 420 g ae ha^{-1} controlled orange hawkweed consistently, with peak injury observed 1 yr after treatment. Control with clopyralid was slightly less than that provided by aminopyralid at all observation times, except at Homer, AK, in 2007, where there was a near-monotypic stand of orange hawkweed, and clopyralid did not remove all orange hawkweed plants. Aminopyralid controlled clover (*Trifolium* spp.), seacoast angelica (*Angelica lucida*), arctic daisy (*Chrysanthemum arcticum*), common hempnettle (*Galeopsis tetrahit*), and willow (*Salix* spp.) in the treated areas. Other plant species, such as grasses and some annual forbs, recovered or increased following control of the hawkweed. Clopyralid had less impact on nontarget species with most recovering the year after treatment. In a pasture system, where grasses are preferred to forbs and shrubs, aminopyralid has an advantage because it controls a broader array of forbs compared with clopyralid. In natural areas, where the desire to retain biodiversity and the aesthetics of multiple forb species mixed with grasses and willows is preferred, clopyralid will leave greater species diversity than aminopyralid.

Nomenclature: Aminopyralid; chlorsulfuron; clopyralid; metsulfuron; picloram; triclopyr; Orange hawkweed, *Hieracium aurantiacum* L. HIEAU; arctic daisy, *Chrysanthemum arcticum* L. CHYAR; clover, *Trifolium* spp.; common hempnettle, *Galeopsis tetrahit* L. GAETE; seacoast angelica, *Angelica lucida* L. ANLU; willow, *Salix* spp.

Key words: Alaska; exotic weeds; greenhouse; nonindigenous plant; weed control.

Orange hawkweed (*Hieracium aurantiacum* L.) is a perennial, rosette-forming plant that reproduces via windblown seed and stolons (Hitchcock and Cronquist 1981). It is native to mountain meadows and hillsides in northern and central Europe (Sell 1974) but has spread across the northern United States and Canada (USDA 2009) since its first report in 1875 in Vermont (Voss and Bohlke 1978). Orange hawkweed was first confirmed in Alaska in 1961 (University of Alaska Museum Herbarium accession 43946) at Tee Harbor, AK, 22 km NW of Juneau, AK (54°N, 134°45′W). It has since spread and is now found on roadsides, in pastures, and in other grassy areas in Alaska, south of the Alaska Range (AKEPIC 2009). Orange hawkweed is ranked as highly invasive in Alaska (Carlson et al. 2008). Because orange hawkweed infestations continue to expand, concerns about its impact on the environment, as well as pastures and fields, have resulted in increased demands for effective control measures.

Orange hawkweed forms patches that increase in density and size vegetatively and establishes new patches through windblown seed (Wilson and Callihan 1999). Near-monotypic stands of orange hawkweed have developed in cemeteries, lawns, and pastures in Alaska (personal observation). One large infestation at the Talkeetna, AK, airport is of particular concern because of the possibility of seed transport to remote areas of the state with air travel. Methods to control the weed are limited because of the opposition to herbicide control by some local residents.

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Interpretive Summary

Land managers are often faced with the task of selecting a weed control treatment from among a wide variety of options. Frequently there are people with a wide variety of concerns, opinions, and ideas that will want to question or even legally challenge the manger's decision. Orange hawkweed is a nonindigenous, invasive plant species that is spreading rapidly in Alaska, and there are few options for its control. Chemical control methods for orange hawkweed have not been studied in Alaska. In addition, there are concerns about impacts on native plant species and hopes that reduced rates of herbicides will result in acceptable control with minimal impacts on other plant species. The results of this research indicate that higher rates of both aminopyralid and clopyralid are needed to effectively control orange hawkweed. In a pasture system, where grasses are preferred to forbs and shrubs, aminopyralid has an advantage because it will control many other species compared with clopyralid, and there will be an increase in grass productivity. In a field, where the aesthetics of multiple forb species mixed with grass and willows is preferred, clopyralid will have a reduced effect on many more of these species than will aminopyralid.

Currently, more than 1,300 sites in Alaska have been documented with orange hawkweed infesting about 100 ha (250 ac) (AKEPIC 2009).

Mechanical control methods have proven to be ineffective and, in the case of mowing, sometimes counterproductive (Wilson and Callihan 1999); however, chemical control methods have been shown to be successful at controlling orange hawkweed. Picloram (at least 140 g ha^{-1} [0.13 lb ac^{-1}]) combined with 2,4-D (at least 275 g ha^{-1}) was effective in controlling flowering orange hawkweed in a pasture in northern Idaho (Wattenbarger et al. 1979). Picloram (440 and 660 g ha^{-1}) and clopyralid (270, 550, and 1,100 g ha^{-1}) caused 80% or more chlorosis of meadow hawkweed (*Hieracium caespitosum* Dumort.) in a northern Idaho pasture (Miller et al. 1987) and plots treated with 550 and 1,100 g ae ha^{-1} of clopyralid continued to control 100, 80, and 50% of the hawkweed 3, 4, and 5 yr after treatment, respectively (Lass and Callihan 1992). However, picloram is not permitted for use in Alaska because of concerns of reduced rates of herbicide degradation in Alaska's cold soils (Conn and Cameron 1988; Conn and Knight 1984), resulting in the potential for increased movement in groundwater.

Using reduced herbicide rates could alleviate the potential of herbicide persistence (Conn and Cameron 1988; Conn and Knight 1984) and movement of herbicides used to control orange hawkweed under cold soil conditions, such as found in Alaska or mountainous regions. The objectives of this research were to determine (1) the dose–response of orange hawkweed to six herbicides (aminopyralid, clopyralid, picloram, picloram + chlorsulfuron, picloram + metsulfuron, and triclopyr) in greenhouse trials, and (2) whether rates of aminopyralid and clopyralid below the maximum label rate for orange hawkweed result in effective orange hawkweed control in field trials.

Materials and Methods

Greenhouse Study. A greenhouse experiment was conducted in November 2006 to January 2007 and repeated in January to March 2007. Orange hawkweed seed collected at Homer, AK, in 2006 were used for the experiments. Seeds were not dormant and had > 90% viability. Seeds were sown in flats (28 by 53 by 6 cm [11 by 21 by 2.4 in]) filled with vermiculite to a depth of 4 cm and placed in a growth chamber.[1] Diurnal settings in the growth chamber were 15/9 h light/dark at 20/15 C (68/59 F) day/night temperatures, respectively. Plants were watered twice daily. After 9 d, seedlings were transplanted into pots (8 by 8 by 8 cm) filled with a commercial potting mix.[2] Because the herbicides chosen were all applied postemergence, an assumption was made that the potting mix would not significantly alter plant response to the herbicides. Seedlings were grown in a U.S. Department of Agriculture (USDA), Agricultural Research Service, greenhouse located at the University of Alaska, Fairbanks, Matanuska Experiment Farm near Palmer, AK, which was maintained at 15/20 C day/night temperatures with supplemental lighting in a 12/12 h day/night cycle. Plants were watered daily and thinned to one seedling per pot at 2 to 3 wk after planting.

Four weeks after transplanting, when plants were at the six- to eight-leaf stage, herbicides (Table 1) were applied using a handheld CO_2 backpack sprayer with a flat-fan nozzle,[3] delivering 187 L ha^{-1} (20 gal ac^{-1}) at 250 kPa. In this study, 13 ml (8 in^3) of herbicide solution were applied to a 0.23-m^2 (0.28 yd^2) area. A nonionic surfactant[4] was added to each herbicide solution at 0.25% (v/v). Before spraying on application day, 10 representative plants were harvested at the soil level, dried at 60 C for 4 d, and weighed to determine initial dry weights. Both experiments were conducted using a randomized complete-block design with four blocks. A nontreated control was included for each herbicide used and there were 10 orange hawkweed plants sprayed for each treatment within a block. Three weeks after treatment (WAT), all plants were visually evaluated for injury, harvested at the soil level, dried at 60 C for 4 d, and weighed. Dry matter accumulation after spraying was determined by subtracting the average initial weights from final weights for each experiment.

Field Study. Based on greenhouse results, two herbicides were selected for field studies in 2007 and 2008 (Table 1). In 2007, two locations, a woodlot in Homer, AK (59°40′26.112″N, 151°40′1994″W) and a hayfield north of Talkeetna, AK (62°19′5.412″N, 151°15′7.9194″W),

Table 1. Herbicides and rates used to evaluate efficacy for control of orange hawkweed in greenhouse and field studies.

Herbicide	Greenhouse		Field	
	1× rate	Fractional rate	1× rate	Fractional rate
	g ae ha^{-1}		g ae ha^{-1}	
Aminopyralid	105	1, 0.5, 0.25, 0.125, 0.0625, 0	105	1, 0.5, 0.25, 0
Clopyralid	420	1, 0.5, 0.25, 0.125, 0.0625, 0	420	1, 0.5, 0.25, 0
Picloram	280	1, 0.5, 0.25, 0.125, 0.0625, 0		
Picloram + chlorsulfuron	280 + 53	1, 0.5, 0.25, 0.125, 0.0625, 0		
Picloram + metsulfuron	280 + 42	1, 0.5, 0.25, 0.125, 0.0625, 0		
Triclopyr + clopyralid	630 + 210	1, 0.5, 0.25, 0.125, 0.0625, 0		

were treated. In 2008, two locations, the same hayfield north of Talkeetna, AK, and an abandoned field in Homer, AK (59°40′37.0194″N, 151°38′17.448″W), were treated. The woodlot was a near-monotypic stand of orange hawkweed, with less than 5% cover of clovers (*Trifolium* spp.), dandelion (*Taraxacum officinale* G.H. Weber ex Wiggers), and field horsetail (*Equisetum arvense* L.). The sites in the hayfield had a poor stand (20% cover) of smooth brome (*Bromus inermis* Leyss.) with some timothy (*Phleum pratense* L.; < 5% cover) and a moderate infestation of orange hawkweed (10 to 20% cover). Forbs, such as dandelion, common yarrow (*Achillea millefolium* L.), thymeleaf speedwell (*Veronica serpyllifolia* L.), fireweed [*Chamerion angustifolium* (L.) Holub], and clover, covered 30 to 40% of the study area. The abandoned field in Homer, AK, had a light infestation of orange hawkweed, usually less than 5% cover, and a dense cover of forbs, such as cow-parsnip (*Heracleum maximum* Bartr.), fireweed, Nootka lupine (*Lupinus nootkatensis* Donn. ex Sims var. nootkatensis), dandelion, field horsetail, woolly geranium (*Geranium erianthum* DC.), and seacoast angelica (*Angelica lucida* L.), with some grasses covering 80% of the study area. Plots were 1.8 by 9.1 m (6 by 30 ft), arranged in a randomized complete-block design, with three blocks. Before treatment, cover by orange hawkweed, grasses, and other species were estimated visually in three randomly placed 0.25-m^2 subplots in each plot. Treatments were applied on June 12 and 13, 2007, and June 9 and 10, 2008, when plants were actively growing but still in the rosette stage. A handheld, variable-rate, log-step sprayer,[5] with a 1.8-m boom and flat-fan nozzles[3] delivering 187 L ha^{-1} was used for treatment applications. A nonionic surfactant[4] was added to each herbicide solution at 0.25% (v/v). Plant response (percentage of control) was visually estimated 2 and 6 WAT in 2007 and 2008, respectively. During the last week in August, 2 mo after treatment (MAT), in both years, vegetation was clipped at ground level in two randomly placed 25 by 25 cm (2 by 2 ft) subplots in each plot. Vegetation in each subplot was separated into *orange hawkweed*, *grasses*, and *other*, dried for at least 72 hr at 40 C, and weighed. One year after treatment (YAT)(June 2008 and July 2009), plant response was again visually estimated in each plot.

Statistical Analyses. Data were determined to be normally distributed using a UNIVARIATE procedure on model residuals with the Shapiro-Wilk statistic in SAS.[6] Data were analyzed as randomized complete-block designs using the general linear models procedure of SAS. There were no differences at similar herbicide doses between the two experiments in the greenhouse, so all data were combined. Because of differences in land use, vegetation, and orange hawkweed populations at the four sites, each site was analyzed separately. Fisher's Protected LSD test was used to separate means.

Results and Discussion

Greenhouse Study. All herbicides reduced plant biomass in the greenhouse trials (Table 2). Aminopyralid at 13 g ae ha^{-1} or greater reduced orange hawkweed biomass compared with the control, and all plants appeared dead when evaluated visually for injury at rates of 27 g ae ha^{-1} or greater. Clopyralid at 105 g ae ha^{-1} or greater reduced orange hawkweed plants more than 50% compared with the control, and all plants appeared dead at rates of 210 and 420 g ae ha^{-1}. Picloram alone reduced orange hawkweed biomass only at the highest rate tested (280 g ae ha^{-1}), and those plants appeared to be dead. The addition of chlorsulfuron or metsulfuron to picloram increased the efficacy of control with more than a 50% reduction in biomass measured at 70 and 149 g ae ha^{-1}, respectively. Only plants at the highest two rates of these herbicide mixtures appeared to be dead. The three highest rates of triclopyr + clopyralid reduced orange hawkweed biomass 68 to 88% compared with the control, and plants at those three high rates appeared to be dead.

Based on these results, all herbicides evaluated had potential for use in the field. However, after discussions with the Alaska Department of Environmental Conserva-

Table 2. Effect of herbicides on orange hawkweed growth in greenhouse experiments. Values are means ± SE (n = 8).[a]

Herbicide	Rate	Dry weight
	g ae ha^{-1}	g
Aminopyralid	0	76 ± 20 a
	7	59 ± 11 a
	13	25 ± 5 b
	27	15 ± 5 b
	53	12 ± 2 b
	105	16 ± 4 b
Clopyralid	0	89 ± 5 a
	26	84 ± 8 a
	53	66 ± 10 a
	105	42 ± 5 b
	210	23 ± 6 b
	420	24 ± 6 b
Picloram	0	93 ± 10 a
	18	97 ± 10 a
	35	86 ± 10 a
	70	74 ± 11 a
	140	68 ± 21 a
	280	30 ± 3 b
Picloram + chlorsulfuron	0	113 ± 17 a
	18 + 3	109 ± 9 a
	35 + 7	114 ± 8 a
	70 + 13	55 ± 6 b
	140 + 27	32 ± 6 bc
	280 + 53	24 ± 7 c
Picloram + metsulfuron	0	98 ± 11 a
	18 + 3	105 ± 15 a
	35 + 5	117 ± 15 a
	70 + 11	105 ± 23 a
	140 + 21	44 ± 8 b
	280 + 42	45 ± 10 b
Triclopyr + clopyralid	0	131 ± 5 a
	39 + 13	107 ± 8 b
	79 + 27	113 ± 10 ab
	158 + 53	43 ± 5 c
	315 + 105	32 ± 6 cd
	630 + 210	16 ± 6 d

[a] Means within an herbicide followed by the same letter are not significantly different according to Fisher's Protected LSD (P = 0.05).

tion, it was clear that the state would not approve the use of picloram, so picloram treatments were not included in the field study.

Field Study. *Homer, AK, 2007.* All rates of aminopyralid and clopyralid injured the almost monotypic stand of orange hawkweed, with no differences in visual control among treatments at 2 WAT (Table 3). Aminopyralid at 105 and 53 g ae ha^{-1} and clopyralid at 420 g ae ha^{-1} had 98% or better control of orange hawkweed at 1 YAT (Table 3). Orange hawkweed biomass was decreased at all rates of aminopyralid and at the two highest rates of clopyralid 2 MAT (Table 4). There was a trend for increased grass biomass (P = 0.06) only at the highest rate of aminopyralid, whereas the two highest rates of clopyralid resulted in increased grass biomass. These plots had very little grass cover before treatments (2 ± 1% SE), and the increase in grass biomass in the first year demonstrated that perennial grass populations were able to expand as orange hawkweed declined. This grass increase continued into the next year, where visual estimates of grass cover were 19 ± 7, 29 ± 9, and 56 ± 6% in plots treated with 26, 53, and 105 g ae ha^{-1} aminopyralid, respectively, with 12 ± 4 and 41 ± 7% grass cover in plots treated with 210 and 420 g ae ha^{-1} clopyralid, respectively; whereas grass cover remained at 2 ± 1% in the control plots. There were no measurable impacts of either herbicide on the overall biomass of other vegetation.

Talkeetna, AK, 2007. At 2 WAT, visual estimates indicated that aminopyralid and clopyralid were reducing a medium orange hawkweed infestation (10 to 20% cover) in the pasture and the highest rate of aminopyralid injured orange hawkweed more than the lowest rate did (Table 3). At 1 YAT, both herbicides at all rates reduced orange hawkweed from 70 to 100%. However, plant biomass measured in August, 2 MAT, at the end of the growing season, was not different among treatments for orange hawkweed, grasses, or other vegetation (Table 4). The cover of the grass component at 1 YAT was 2 ± 1% in the control plots and 5 ± 2, 17 ± 4, and 16 ± 4% in plots treated with 27, 53, and 105 g ae ha^{-1} aminopyralid and 6 ± 3, 16 ± 4, and 17 ± 6% in plots treated with 105, 210, and 420 g ae ha^{-1} clopyralid, respectively, with the highest two rates of each herbicide resulting in increased grass cover (P = 0.0006).

Homer, AK, 2008. There were no significant differences in visual control estimates among treatments at 2 WAT (Table 3). The combination of a light infestation (< 5% cover) of orange hawkweed and the dense canopy of taller vegetation may have reduced herbicide efficacy. A year later, there was no orange hawkweed in the plots treated with the 105 g ae ha^{-1} rate of aminopyralid, and the 420 g ae ha^{-1} rate of clopyralid resulted in 98% control of this weed species. There were no differences in plant dry weight between herbicides and among rates for orange hawkweed, grass, and other plants (Table 4).

Talkeetna, AK, 2008. The 105 g ae ha^{-1} rate of aminopyralid resulted in 95% control 2 WAT and 100% control 1 YAT (Table 3). Although there were differences in control among the clopyralid rates at both observation times, none of the rates resulted in acceptable control of orange hawkweed. All rates of aminopyralid reduced the

Table 3. Effect of herbicides on orange hawkweed as a percent of nontreated control in four field experiments. Values are means ± SE (n = 3).[a,b]

Site/Year (Alaska)	Herbicide	Rate	2 WAT	1 YAT
		g ae ha^{-1}	% of control	
Homer 2007	Aminopyralid	105	78 ± 9	100 ± 0 a
		53	83 ± 3	98 ± 2 a
		26	67 ± 9	51 ± 21 b
	Clopyralid	420	73 ± 4	100 ± 0 a
		210	43 ± 22	59 ± 7 b
		105	32 ± 20	24 ± 18 b
Talkeetna 2007	Aminopyralid	105	93 ± 3 a	100 ± 0
		53	83 ± 8 ab	98 ± 2
		26	63 ± 7 b	91 ± 7
	Clopyralid	420	82 ± 7	99 ± 1
		210	70 ± 12	87 ± 13
		105	67 ± 8	69 ± 26
Homer 2008	Aminopyralid	105	90 ± 5	100 ± 0
		53	80 ± 8	55 ± 37
		26	90 ± 4	65 ± 4
	Clopyralid	420	83 ± 7	98 ± 2 a
		210	70 ± 12	3 ± 2 b
		105	55 ± 4	5 ± 4 b
Talkeetna 2008	Aminopyralid	105	95 ± 0 a	100 ± 0 a
		53	82 ± 2 b	63 ± 13 b
		26	73 ± 2 c	32 ± 9 b
	Clopyralid	420	80 ± 5 a	58 ± 14 a
		210	75 ± 0 a	18 ± 16 ab
		105	58 ± 4 b	7 ± 3 b

[a] Abbreviations: WAT, weeks after treatment; YAT, years after treatment.

[b] At each site, means within a herbicide time followed by the same letter are not significantly different according to Fisher's Protected LSD (P = 0.05).

dry weight of orange hawkweed and forbs compared with the control (Table 4). All rates of clopyralid reduced the dry weights of forbs compared with the control plots.

Impacts on Nontarget Plant Species. To make informed choices about which herbicides to use to control weeds, it is important to know the consequences of their use. Nontarget effects of herbicides are important in both managed and unmanaged locations. For orange hawkweed control, this information is needed to choose the herbicide that will have the fewest detrimental effects on desired species. In addition, many plant species common to coastal and boreal ecosystems in Alaska have not been tested for sensitivity to aminopyralid or clopyralid. The results of our research show that Thymeleaf speedwell, fern, and Alaska Indian paintbrush [*Castilleja unalaschcensis* (Cham. & Schlecht) Malte] were tolerant to all rates of these two herbicides (no observed injury), whereas clovers were removed by all rates of both herbicides. For some nontarget plant species, injury from the lower rates of one or both herbicides was not lethal or the injury was only temporary (Table 5). American dragonhead (*Dracocephalum parviflorum* Nutt.) and goldenrod (*Solidago* spp.) in plots treated with either herbicide or yellow-rattle (*Rhinanthus minor* L.) in plots treated with aminopyralid were not observed in the plots until 1 YAT, probably representing a release from competition as a consequence of the herbicide use.

Across experiments, only aminopyralid at 105 g ae ha^{-1} and clopyralid at 420 g ae ha^{-1} controlled orange hawkweed consistently, with peak injury observed 1 YAT. Both of these rates are at the highest recommended label rate for orange hawkweed. Clopyralid was slightly less efficacious at all observation times, except for Homer, AK, 2007, where there was a near monotypic stand of orange hawkweed, and clopyralid did not remove all orange hawkweed plants. At 105 g ae ha^{-1}, aminopyralid removed clover, wild celery, arctic daisy, common hempnettle, and willow from the treated areas. Other plant species (Table 5) would either recover or, as in the case of grasses and some annual forbs, increase. Clopyralid at 420 g ae ha^{-1} had less

Table 4. Effect of herbicides on dry weight of orange hawkweed, grasses and other vegetation in four field experiments. Dry weight measurements were made 2 mo after treatment. Values are means ± SE (n = 6).[a]

Farm/year (Alaska)	Herbicide	Rate	Dry weight		
			Orange hawkweed	Grass	Other
		g ae ha^{-1}	g 625 cm^{-2}		
Homer 2007	Aminopyralid	105	0.5 ± 0.3 b	6.1 ± 2.1	1.7 ± 0.9
		53	2.6 ± 2.0 b	4.0 ± 1.7	4.0 ± 1.5
		26	4.1 ± 1.2 b	2.8 ± 1.2	2.9 ± 0.9
		0	12.2 ± 2.3 a	0.8 ± 0.4	1.2 ± 0.7
	Clopyralid	420	0.1 ± 0.04 b	2.7 ± 0.6 a	4.7 ± 1.6
		210	4.2 ± 1.0 b	2.2 ± 0.7 a	4.6 ± 2.4
		105	11.5 ± 1.7 a	0.8 ± 0.2 b	3.4 ± 1.1
		0	12.2 ± 2.2 a	0.8 ± 0.4 b	1.2 ± 0.7
Talkeetna 2007	Aminopyralid	105	2.8 ± 1.5	7.6 ± 1.9	1.9 ± 1.6
		53	1.2 ± 0.5	8.6 ± 2.1	2.2 ± 1.9
		26	3.6 ± 1.2	6.6 ± 1.2	2.3 ± 0.9
		0	4.1 ± 1.9	4.6 ± 1.2	4.3 ± 0.6
	Clopyralid	420	4.6 ± 1.9	6.4 ± 2.4	0.6 ± 0.2
		210	3.1 ± 1.6	6.4 ± 1.5	2.4 ± 1.0
		105	4.1 ± 1.4	6.6 ± 1.2	2.3 ± 2.0
		0	4.1 ± 1.9	4.6 ± 1.2	4.3 ± 0.6
Homer 2008	Aminopyralid	105	0.01 ± 0.01	0.9 ± 0.3	4.8 ± 2.2
		53	0.3 ± 0.2	0.7 ± 0.3	5.6 ± 1.8
		26	0.3 ± 0.2	0.4 ± 0.2	9.5 ± 6.5
		0	0.8 ± 0.6	0.8 ± 0.6	17.7 ± 10.8
	Clopyralid	420	0.1 ± 0.1	0.7 ± 0.2	4.7 ± 2.3
		210	0.7 ± 0.2	0.8 ± 0.2	9.2 ± 5.9
		105	0.3 ± 0.1	1.3 ± 0.6	9.6 ± 5.2
		0	0.8 ± 0.5	0.8 ± 0.5	17.7 ± 10.8
Talkeetna 2008	Aminopyralid	105	0.3 ± 0.1 b	2.4 ± 0.6	0.2 ± 0.1 b
		53	1.5 ± 0.5 b	0.7 ± 0.2	1.1 ± 0.3 b
		26	2.8 ± 0.9 b	1.0 ± 0.2	0.9 ± 0.2 b
		0	7.5 ± 2.0 a	1.3 ± 1.0	3.8 ± 1.2 a
	Clopyralid	420	3.4 ± 1.3	1.9 ± 1.4	0.7 ± 0.2 b
		210	5.6 ± 1.7	1.1 ± 0.5	0.6 ± 0.2 b
		105	3.3 ± 1.8	2.9 ± 0.8	1.1 ± 0.2 b
		0	7.5 ± 2.0	1.3 ± 1.0	3.8 ± 1.2 a

[a] At each site, means within a herbicide time followed by the same letter are not significantly different according to Fisher's Protected LSD (P = 0.05).

impact on many of the nonhawkweed species, with most recovering a 1 YAT. Only yarrow was slow to recover (Table 5). In a pasture system, where grasses are preferred to forbs and shrubs, aminopyralid has an advantage because it will control many other broadleaf species compared with clopyralid, which has less activity on nontarget broadleaves. In a field in which the aesthetics of multiple forb species mixed with grass and willows is preferred, clopyralid will leave greater species diversity than aminopyralid.

Greenhouse data indicated that there were no differences for control of orange hawkweed for rates of aminopyralid from 13 to 105 g ae ha^{-1}. Biomass measures of orange hawkweed in the field resulted in a similar conclusion. However, visual observations at 1 YAT showed that only the 105 g ae ha^{-1} rate consistently controlled orange hawkweed in the field. In the greenhouse studies, clopyralid efficacy was reduced when rates dropped from 420 to 105 g ae ha^{-1}. This drop in orange hawkweed efficacy was also measured in the field from biomass measures made 2 MAT at the Homer, AK, 2007 site and with visual observations at 1 YAT at all but the Talkeetna, AK, 2007 site. Preliminary greenhouse trials for determining the efficacy of aminopyralid and clopyralid for control of orange hawkweed were useful predictors of results in the field.

Table 5. Herbicide injury to nontarget plant species the year of, and the year after, treatment. Numbers are averages from all experiments.[a]

		Aminopyralid			Clopyralid		
		g ae ha^{-1}					
Common name	Scientific binomial	105	53	26	420	210	105
		% injury					
Seacoast angelica	*Angelica lucida* L.	100–100[b]	T	T	T	T	T
Quaking aspen	*Populus tremuloides* Michx.	—	—	—	T	T	T
Paper birch	*Betula papyrifera* Marsh. var. *papyrifera*	20–10	40–0	10–0	T	T	T
Arctic daisy	*Chrysanthemum arcticum* L.	75–95	?–0	65–0	70–0	55–0	45–45
Dandelion	*Taraxacum officinale* G.H. Weber ex Wiggers	70–10	45–10	40–20	60–10	45–10	60–5
Fireweed	*Chamerion angustifolium* (L.) Holub	60–40	35–40	40–40	50–30	45–5	40–0
Woolly geranium	*Geranium erianthum* DC.	70–0	35–0	55–40	25–10	30–5	20–0
Nootka lupine	*Lupinus nootkatensis* Donn. ex Sims var. *nootkatensis*	95–30	10–0	?–0	65–0	65–0	?–0
Common hempnettle	*Galeopsis tetrahit* L.	85–100	80–100	50–0	T	T	T
Rough cinquefoil	*Potentilla norvegica* L.	—	—	—	T	T	T
Cow-parsnip	*Heracleum maximum* Bartr.	—	—	—	T	T	T
Red sorrel	*Rumex acetosella* L.	—	—	—	T	T	T
Canadian burnet	*Sanguisorba canadensis* L.	—	—	—	T	T	T
Beauverd spirea	*Spiraea stevenii* (C.K. Schneid.) Rydb.	—	—	—	T	T	T
Spruce	*Picea* sp.	60–45	40–20	5–15	T	T	T
Willows	*Salix* spp.	50–100	10–0	25–0	T	T	T
Common yarrow	*Achillea millefolium* L.	50–75	75–20	60–20	65–55	80–0	65–5

[a] Abbreviations: T, tolerant; ?, plant not found; —, no plants in plots.

[b] First number is the percentage of injury from observations made 2 to 6 wk after treatment, and second number is the percentage of injury from observations made 1 yr after treatment, compared with control (0, no injury; 100, all dead)

Sources of Materials

[1] Conviron CMP4030, Controlled Environments ltd., 590 Berry St. Winnipeg, MB R3H 0R9, Canada.

[2] Premier Horticulture Inc., 127 South 5th Street, No. 300, Quaker Town, PA 18951.

[3] 8002 VS nozzle, Tee-Jet Spraying Systems Co., Wheaton, IL 60139.

[4] Kenetic, Helena Chemical Company, 225 Schilling Blvd., Suite 300 Collierville, TN 38017.

[5] R&D Sprayers, 419 Highway 104, Opelousas, LA 70570.

[6] Statistical software, Version 9.1, SAS Institute, Inc., Cary, NC 27513.

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