Sensitivity to herbicide in the north: toxicity of imazapyr and triclopyr to Yukon ROW target and non-target plants

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ABSTRACT

The toxicity of herbicides has been the subject of extensive study; however, how these products interact with boreal species in northern climates has received little attention. As part of a larger project investigating vegetation management strategies for power line rights-of-way in Yukon, Canada, the objective of this study was to determine the impact of herbicide use on target and non-target plant species. At four sites in Yukon, Arsenal Powerline and Garlon XRT were applied to vegetation using three application methods: foliar spray, cut stump and point injection. Target species were identified as trembling aspen, balsam poplar, willows and Alaska birch. All other vegetation was considered non-target. Visual damage assessments were completed after 30 and 365 days. There were significant differences in efficacy of treatments after 30 days, but these differences largely disappeared after 365 days. All combinations of herbicide and application method were highly effective on target species. Damage to non-target erect shrubs, however, was significantly different across herbicide and application methods. Arsenal Powerline caused more damage overall than Garlon XRT and broadcast spraying was the most damaging application method, followed by cut stump and point injection. With all treatments causing similar damage to target species, reducing impacts on non-target shrubs may be considered a priority when evaluating vegetation management options.

KEY WORDS

Herbicide, imazapyr, right-of-way, tree invasion, triclopyr, vegetation management

INTRODUCTION

There are more than 1000 km of power line right-of-way (ROW) in Yukon, Canada. Vegetation within the 30 m corridors has historically been managed by mechanical methods. Trembling aspen (*Populus tremuloides)*, balsam poplar (*Populus balsamifera),* Alaska birch *(Betula neoalaskana)*, and willows (*Salix spp*.) are the most common species requiring control as they grow quickly after disturbance and are tall enough to interfere with transmission lines. Many of these species reproduce clonally and observations from operation managers are consistent with other ROW vegetation management research: cutting/mowing results in an increase in stem density and canopy cover of target species (Yahner and Hutnik 2004).

The body of research into alternatives to mechanical control has been growing steadily since the late 1950s. Results in southern jurisdictions suggest vegetation management strategies can be designed to encourage the growth of desirable, low growing species and limit regrowth of target species (Niering and Goodwin 1974, Dreyer and Niering 1986, Bramble et al. 1991, Nowak 1993, Meilleur et al. 1994, Yahner and Hutnik 2004). The mechanisms of how ecosystems resist the regrowth or invasion of target species are not always clear, but the success of shrub covers are consistently related to high stem densities and canopy cover of erect shrubs (Dreyer and Niering 1986, Meilleur et al. 1994, Ballard 2006).

Preserving or enhancing the erect shrub layer is often accomplished with selective herbicide use, a strategy which may also be effective in northern environments (Niering and Goodwin 1974, Dreyer and Niering 1986, Meilleur et al. 1994, Mercier et al. 2001). A recent review of forestry-use herbicides was completed by local consulting company Environmental Dynamics Inc. and, after a small-scale field trial, triclopyr and imazapyr were identified as having the most potential for use on Yukon ROWs (EDI 2013).

Triclopyr is a pyridine-base Group 4 herbicide in the carboxylic acid family. It was first registered in Canada in 1989 for use on broadleaf and woody vegetation in non-crop areas. Similar to the phenoxyacetic acids (e.g., 2,4-D) and benzoic acids (e.g., dicamba), triclopyr acts as an auxin mimic, effectively giving the plant a hormone overdose. It typically degrades rapidly in both soil and water by microbial breakdown or photolysis. Imazapyr is a broad spectrum Group 2 herbicide in the imidazolinone family. First registered in Canada in 1994, it is typically used to control grasses, broad-leaf weeds and select perennial shrubs. Like the sulfonylurea family (e.g., metsulfuron), imidazolinone herbicides inhibit the production of three amino acids by binding to the acetolactate synthase (ALS) enzyme and are most effective on young, actively growing plants. Imazapyr can be applied pre- or post-emergence and can remain active and mobile in soils for an extended period of time (Bovey and Senseman 1998).

Though the efficacies of both these herbicides have been the subject of considerable research in the past, southern research cannot be directly applied to northern ecosystems due to the difference in species, climate and soil types. The efficacy of the treatment on target species is a critical component as even intact shrub communities have not been found to inhibit tree reproduction through suckering (Dreyer and Niering 1986). Maintaining the erect shrub layer is the secondary goal of treatments to determine if a tree/tall shrub resistant community may be established. Encouraging low growing plant communities has the potential to reduce both the costs and environmental impacts of vegetation management on Yukon ROWs. As part of a larger risk assessment, this study focuses on identifying the efficacy of imazapyr and triclopyr applications on target trees/tall shrubs and subsequent effects on non-target low growing shrubby species.

METHODS

For a field trial, four sites were selected throughout the territory to represent different biogeoclimatic zones and soil types. Two sites were on the Alaska Highway, 75 and 110 km west of Whitehorse and two were on the North Klondike Highway, 160 and 480 km north of Whitehorse. Sites were laid out in a randomized complete block design with three blocks of six treatments. The 6 m x 6 m treatment plots were spaced at a minimum of 50 m apart to ensure no interference between treatments (i.e., herbicide drift). The six treatments applied to Yukon ROWs were designed to represent application options of both herbicides (Table 1). The commercial formulations Garlon XRT and Arsenal Powerline were chosen for the project and contained 755 g/L triclopyr butoxyethyl ester and 240 g/L imazapyr acid respectively.

Table 1: Descriptions of treatment methods tested on Yukon ROWs

Plot	Treatment
T1	Foliar Spray – Garlon XRT
T2	Foliar Spray – Arsenal PowerLine
T3	Cut Stump – Garlon XRT
T4	Cut Stump – Arsenal PowerLine
T5	Point Injection – Garlon XRT
T6	Point Injection – Arsenal PowerLine

Treatments were applied at each site between mid-July and early August 2014. To simulate broadcast spraying, backpack sprayers were used to apply Garlon XRT and Arsenal Powerline at the maximum allowable rate for each herbicide. Cut stump and point injection formulations were also mixed at the recommended concentration with Garlon XRT in canola oil and Arsenal Powerline in deionized water. For cut stump, pruning shears or small saws were used to manually remove trees and herbicide was applied with a paint brush. Point injection was achieved by making an incision on small stems (<2 cm diameter) with a utility knife or drilling into larger stems and applying herbicide with a small syringe.

At 30 and 365 days after treatment (DAT), visual assessments of damage were conducted to evaluate the sensitivity of target and non-target species to each treatment. Yukon target species were identified based on two characteristics: rapid regrowth after disturbance and the ability to grow tall enough to interfere with transmission lines. Trembling aspen (*Populus tremuloides)*, balsam poplar (*Populus balsamifera),* Alaska birch *(Betula neoalaskana)*, and willows (*Salix spp*.) were all designated as species of concern. Non-target erect shrubs commonly found on the ROWs included prickly rose (*Rosa acicularis*), soapberry (*Shepherdia canadensis*), bog bilberry (*Vaccinium uliginosum*) and Labrador tea (*Rhodedendron groenlandicum*).

A scale of 0-100 was used to rate damage to each group, with 0 being no damage and 100 being completely dead. Targets were evaluated by species, or genus in the case of willows, and non-target shrubs were evaluated as a group. Photos of each plot were also taken. To accurately differentiate between natural and herbicide damage, the unaffected area surrounding the plot was used as a control.

Linear mixed-models were used with Site and Block as random factors. Data was divided between target and non-target species (erect shrubs). Target species were again divided as Alaska birch only occurred at one site and was thus modelled separately from aspen, poplar and willows. For the three targets, species was added as a variable for the analysis and site removed as a random effect from the Alaska birch analysis. Assumptions of normality and homogeneity of variance were evaluated post hoc by fitted vs. residuals scatterplots and QQ plots. One outlier was removed in the 30 DAT analysis due to a recording error. Damage data to non-target shrubs were log transformed to meet the assumptions of ANOVA before modelling.

An analysis of variance with Type I sums of squares was used to determine significance of fixed effects in both models ($p<0.05$). Differences between least squared means of each factor combination were generated in R library "lmerTest" and sorted to assess differences within treatments ($p<0.05$) (Kuznetsova et al. 2014). All data were analyzed in R version 3.1.2 (R Core Team 2014).

RESULTS

30 DAT – TARGETS

Garlon XRT was more effective overall than Arsenal Powerline with a mean of 61.9% damage compared to 36.7%. Foliar spray and point injection caused more visual damage than cut stump application regardless of herbicide. Poplar displayed the most resistance to damage from both herbicides and aspen and willows were equally sensitive.

Focusing on differences between species, aspen had the greatest difference in response to cut stump compared to the other two application types (Figure 1.). As seen with poplar and willows, aspen showed no significant differences in damage from spray or point injection applications. Poplar was also not significantly more damaged by point injection than cut stump. Damage to willows, however, was not different across any application type.

Damage to Alaska birch followed the same patterns as the other species. Garlon XRT caused more damage (85.5%) than Arsenal Powerline (53.9%) regardless of application type. Birch responded similarly to point injection and spray applications, but was significantly less sensitive to cut stump application. As seen with the other target species, the combination of herbicide and application methods did not influence the damage.

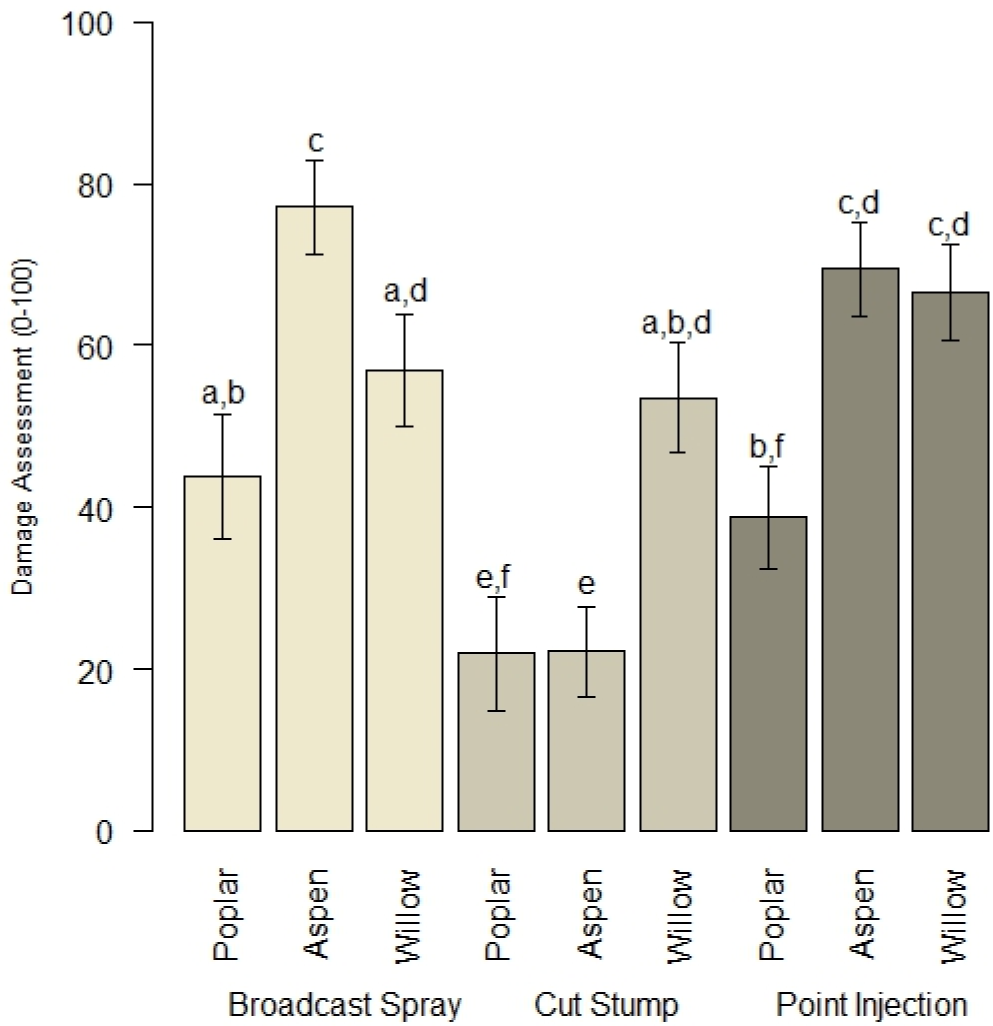

Figure 1. Damage to target species by application type 30 days after treatment, with 0 being no damage and 100 being completely dead. Error bars represent standard error; different letters correspond to significantly different observed damage

365 DAT – TARGETS

The results of the 365 DAT analysis distinctly differed from the 30 DAT findings. There were much fewer significant differences as the vast majority of assessments were very high (above 80%). When all factors were included in the ANOVA, differences in species' response to application type were observed (p=0.018). The effect was most pronounced in broadcast spray plots where trembling aspen was more damaged (99%) than willow (90%) and poplar (83%).

Analysis of Alaska birch showed the species followed similar patterns to the other three targets. Herbicide and the herbicide by application type interactions were not found to cause significantly different damage. Application type affected the amount of damage, with cut stump more damaging to Alaska birch (99.8%) than spray (93.0% (ANOVA, p=0.028)). Damage from point injection was similar to that caused by both cut stump and spray (97.2%).

365 DAT – NON-TARGET ERECT SHRUBS

Damage to erect shrubs 365 DAT followed very distinct patterns and all explanatory factors in the mixed-model were significant: herbicide, application type and herbicide by application type interactions. Arsenal Powerline overall caused significantly more damage with a mean of 32.9% than Garlon XRT (3.8%). As expected, broadcast spray (28.5%) was more damaging than cut stump (12.8%) and point injection (2.8%).

Of all the treatments, Arsenal Powerline cut stump and Arsenal Powerline broadcast spray caused the most damage to erect shrubs (Figure 2.). Arsenal Powerline point injection and Garlon XRT broadcast spray were moderately damaging at 17.0% and 17.5% respectively. Garlon XRT cut stump caused minimal damage (3.6%) and Garlon XRT point injection essentially caused no damage at all (0.9%).

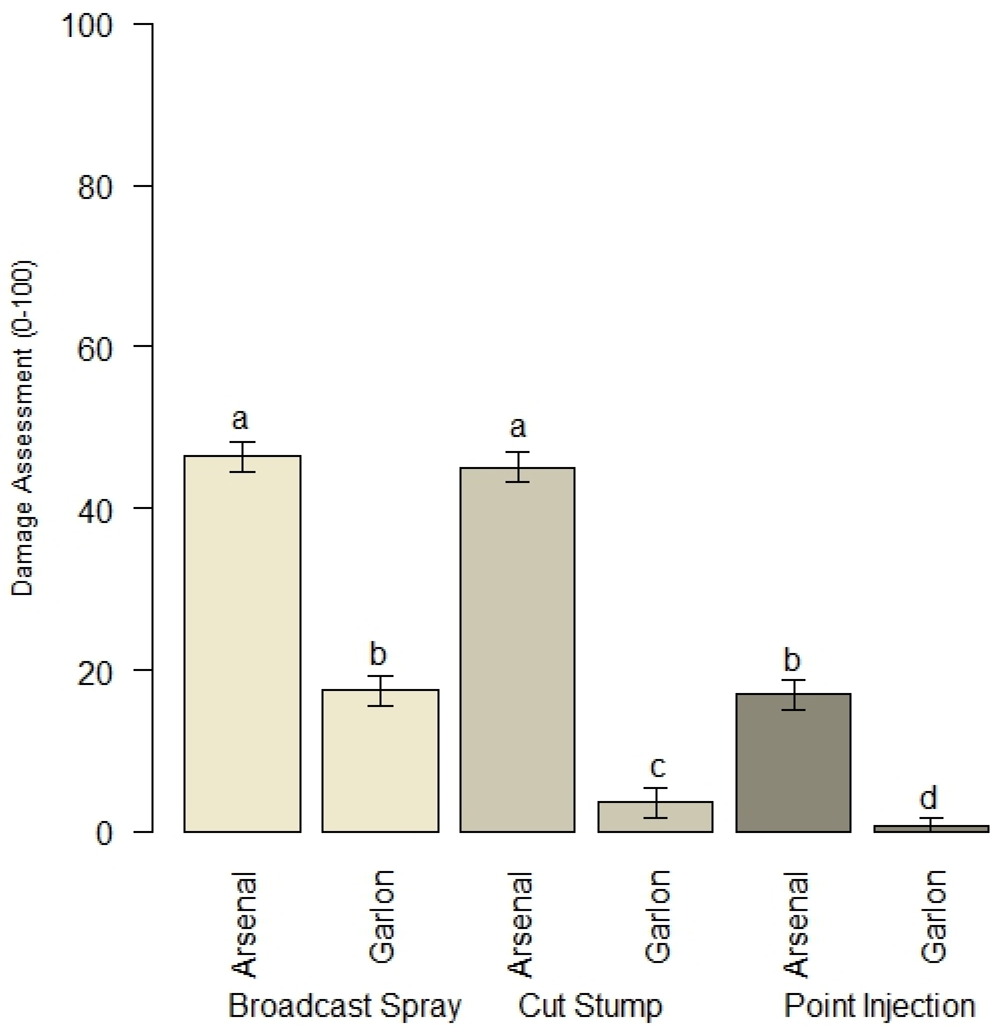

Figure 2. Damage to non-target erect shrubs by herbicide and application type, with 0 being no damage and 100 being completely dead. Error bars represent standard error; different letters correspond to significantly different observed damage.

DISCUSSION

Visual damage assessments after herbicide applications are one of many ways of evaluating injury and are typically used when destructive sampling is not appropriate. Despite inherent limitations due to subjectivity, results from the assessment after 30 and 365 days were remarkably clear. The very large increase in damage to target species between 30 and 365 DAT indicates that 30 DAT assessments are not good indicators of treatment efficacy in Yukon. It also strongly suggests, that while Garlon XRT acts faster on northern target species, ultimately Arsenal Powerline is just as effective. The 365 DAT assessments also confirmed that cut stump, though hard to assess 30 DAT, caused similar damage to targets as point injection and broadcast spray. Because this study is field based, it is important to acknowledge that the impact of the treatment is not exactly the same as the direct toxicity of the herbicide. Factors such as interspecific competition and stress from pest outbreaks also influence the sensitivity of species to herbicides.

Another consideration is the type of damage assessment used. Damage assessments are typically completed on crops, annuals or short lived perennials, not woody tree or shrub species. The recovery capability of northern target species is unknown. A single stalk of oat typically won't recover from 99% damage, but a willow that produces tiny buds after 365 days may recover. It remains unknown whether target species will continue to show increasing or decreasing damage over time. A further assessment two years after treatment may yield information on recoveries of damaged plants.

Species sensitivity to the different herbicides and application methods was less directly evident in the 365 DAT analysis. The significant interaction between application type and species is consistent with observations made in the field. It was noted that aspen regularly appeared completely dead (damage=100) unlike willow or poplar which often produced small, though often deformed, buds at 365 DAT. We did find aspen to be most damaged with a mean of 97.4% compared to willows (94.0%) and poplar (90.7%), however these differences were not statistically significant. Alaska birch cannot be directly compared as it was analyzed separately, but showed similar sensitivity with average damage near 97%.

The lack of significant differences in target efficacy between herbicides and application types allows for more emphasis on avoiding damage to non-target erect shrubs in decision making. With the potential for non-target species to limit target regrowth and invasion, these data strongly suggest selectively applied Garlon XRT is the preferable option. Of note, damage by Garlon XRT broadcast spray, the most damaging application method, was similar to that caused by Arsenal Powerline point injection, the least damaging method. This pattern suggests that Arsenal Powerline remains soil active after application and is bioavailable to non-target shrubs the following year after application. This is most evident in the point injection treatments where erect shrubs would not have been directly exposed to herbicide at the time of application. Shrubs in Garlon XRT treated plots showed virtually no damage (mean of 0.85%) and Arsenal Powerline treated plots caused an average of 17.0% damage.

Deformity in leaves and growth patterns as well as chlorosis (yellowing) clearly indicated that this damage was herbicide related in the Arsenal Powerline point injection plots (Figure 3a-c.). The mechanism by which Arsenal Powerline transfers from target species to the soil after point injection treatments is unclear. It is likely that the imazapyr either concentrated in the leaves and was deposited on the soil surface as litter or was exuded through the root systems of target species. Target species foliage (when present), stem and root samples collected at 30 and 365 DAT and will be tested for herbicide residues in the fall of 2015. These data will aid in the identification of the source. This unexpected result from a selective application method highlights the need for small scale trials when considering new management options.

Figure 3. Effects of Arsenal Powerline point injection treatments on Labrador tea (a), prickly rose (b) and bog bilberry (c) 365 days after treatment.

CONCLUSIONS

The damage assessments presented above are only a component of a much larger study investigating potential vegetation management methods for Yukon ROWs. The results show that based strictly on target control efficacy, there are few differences between imazapyr and triclopyr as well as application methods. Both triclopyr and imazapyr were equally efficacious on trees and tall shrubs. Choice of herbicide and application method does, however, appear to have significant impact on non-target erect shrubs. This is an important consideration as many non-target species are beneficial to have on the ROWs. Maintaining a low growing vegetation community is widely considered to be the ultimate goal of Integrated Vegetation Management (IVM) on ROWs (McLoughlin 2014). The species that have the most inhibition potential depend on site conditions, but understanding the local ecosystem and pest dynamics is a critical component of an IVM plan (Nowak 2014). Our results indicate that imazapyr caused more damage to non-target erect shrubs than triclopyr. Whether this pattern will be strengthened or refuted by other experiments within the study is unclear, but these initial results will assist in developing a vegetation management strategy for Yukon ROWs.

Further investigation into damage to forb and grass species, changes in plant community composition and persistence of herbicide in vegetation tissue will continue as part of the larger project. Additional greenhouse experiments including standard phytotoxicity tests are also being conducted to further identify toxicity of imazapyr and triclopyr to important native forb species. The seeding of aggressive native grasses, both in conjunction with chemical applications and on their own, is also being studied as a potential management strategy. Other researchers on the project are examining imazapyr and triclopyr behaviour in soil and impacts on soil invertebrates. The overall goals of the project are to establish an understanding of Yukon ROW plant community dynamics in response to different management strategies, evaluate environmental risks associated with herbicide use in the north, and develop potential options for ROW managers that are specific to local conditions.

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