RESEARCH NOTE

Treating a Single Stem Can Kill the Whole Shrub: a Scientific Assessment of Buckthorn Control Methods

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ABSTRACT: The exotic, invasive shrub European buckthorn (*Rhamnus cathartica*) is a major threat to natural areas in North America. While many publications describe buckthorn eradication methods, few compare the efficacy of different methods, and none are comprehensive. In this study, we tested the efficacy of 15 combinations of five commonly used herbicides and two physical interventions (cutting and girdling) on the regrowth of 317 buckthorn shrubs in northeastern Illinois. Treatments were performed randomly on plants with primary stems ≥3 cm, and effects on treated stems, untreated stems of multi-stemmed shrubs, and all stems were evaluated six months later. We found neither physical nor chemical methods alone to be optimal, but rather a combination of cutting or girdling with certain herbicides was best. We found Roundup Pro (Roundup), Stalker, and Tordon RTU (Tordon) to be more effective than either Garlon 4 or Brushmaster. Importantly, our data suggests that girdling or cutting of a single stem of multiple-stemmed buckthorn before using Roundup, Stalker, or Tordon usually results in the death of the entire shrub, thereby potentially saving a great deal of time and money. All herbicides were rated equally safe for human applicators by manufacturers, and required approximately equal time and effort to apply. Though Roundup was the most expensive of the three most effective herbicides, manufacturers' labels indicated that it is potentially safest for use in dry natural areas. However, none of the herbicides evaluated are appropriate for use in water, wetland areas, or in areas below mean high water marks.

Index terms: control methods, cut stump, girdling, herbicides, *Rhamnus cathartica*

INTRODUCTION

Common or European buckthorn, *Rhamnus cathartica*, is an exotic, highly-invasive shrub that has become a significant pest across the north central region of North America. Introduced by European settlers in the early 1800s for hedges, forestry uses, and wildlife habitat (Wyman 1971), by the early 1900s it had become widespread (Howell and Blackwell 1977). *R. cathartica* has spread across the North American Midwest. Its hardiness and ability to spread rapidly pose a significant threat to the preservation of natural areas (e.g., Kiernan 1999, Frappier et al. 2003).

While there are several published reports of control methods for buckthorn (Kline 1981, Apfelbaum 1984, Hefty 1984, Converse 1985, Heidorn 1991, Boudreau 1992, Archibold et al. 1997, Reinartz 1997), there are no comprehensive studies that compare and evaluate both physical and chemical control methods. In this study, we tested 15 combinations of five commonly used herbicides and two physical interventions (cutting and girdling) on the regrowth of 317 buckthorn shrubs in northeastern Illinois. Treatments were applied randomly to plants with primary (largest) stems ≥3 cm in late fall 2004. Eradication methods were evaluated six months later in late spring 2005. A novel aspect of this study is that we treated only a single stem of multiple-stemmed shrubs, thereby hoping to determine whether any treatment of a single stem could eradicate the entire shrub, and potentially and enormously reducing labor and material costs. Treatments were also evaluated for relative human safety, relative environmental safety, expense, and ease of application.

METHODS

Study Site

Fifteen different eradication treatments were applied to 297 randomly tagged buckthorn shrubs dispersed over a 0.59 ha area in northeastern Illinois. An additional 20 control shrubs were tagged without treatment for a total sample of 317. The study site was located at the southern edge of Ryerson Woods, Lake County Forest Preserve, Illinois (42.1795° N, 87.9149° W). The site is bordered on the west by an abandoned country lane and on the south by a heavily trafficked four-lane highway. The north and east sides are contiguous with Ryerson Woods. The primary composition of the woodland study site was mixed maple/oak (*Acer spp./Quercus spp.*) forest interspersed with birch (*Betula* spp.) and ash (*Fraxinus* spp.). Buckthorn shrubs were dense within the understory and ranged in size from less than 1 cm to 19 cm in diameter.

Treatment & Application

The 15 treatment methods were comprised

of combinations of five chemical (herbicide, Table 1) and two physical interventions (cutting and girdling). Girdling was completed by cutting (with a Woodsman's Pal; Pro Tool Industries) an approximately 5 cm swath around the circumference of the buckthorn stem at approximately 50 cm above the ground, thereby severing the cambium layer and interrupting the flow of food between the leaves and the rest of the tree. Cut shrubs were sawed off close to ground level using handsaws.

Herbicides were applied using individual hand pump sprayers for each herbicide with the spray width set to stream to limit overspray. Basal bark application was completed by directly spraying herbicide onto the bark in an approximately 5 cm swath around the circumference of the buckthorn stem approximately 50 cm above the ground. Two of the herbicides, Roundup Pro (Roundup) and Tordon RTU (Tordon), are not recommended for basal bark application by the manufacturer (DOW AgroSciences 1997b, Monsanto Co. 2001) and were not so used. Herbicide was applied to girdled or cut stumps by saturating the area of the stem exposed by the cutting or girdling.

We also attempted to use an ArborSystems Wedge Direct-Inject System tree injector (ArborSystems LLC) as one of our herbicide application methods. However, most of the stems available for our experiment were less than the recommended 5.1 cm diameter minimum. Also, we found that due to the thin bark of *R. cathartica*, an inconsistent amount of herbicide could be delivered, because of leakage from the injection site. Consequently, we felt any results from the injection application would be inconclusive, and the method was not included.

The treatments were completed randomly over the course of seven days in late October and early November 2004. Only shrubs with primary stems ≥3 cm in diameter were selected. Randomization was completed by first assigning treatments to tree tags numbered 1-320. All tags were then mixed in a cloth bag. Blindly choosing a tag from the bag and completing the treatment assigned to the number on the tag determined treatments. All shrubs were treated, tagged, and flagged for easier relocation during the evaluation phase. At the time of treatment, the diameter of the largest stem was measured and the total number of stems ≥3 cm was recorded.

Table 1. Herbicide used in this study with manufacturer, active ingredients, and dilutants.

Herbicide (Manufacturer)	Active Ingredients	Dilutants	Final Dilution (Herb./Dilutant)
Brushmaster (GPBI/Gordon Corp.)	Isooctyl (2-ethylhexyl) ester of 2,4-dichlorophenoxyacetic acid	Diesel Oil	10 oz./1 gallon
	2-ethylhexyl ester of (+)-R-2-(2,4-dichlorophenoxy) propionic acid		
	Dicamba: 3,6-dichloro-o-anisic acid		
Garlon 4 (DOW AgroSciences)	Triclopyr: 3,5,6-trichloro-2-pyridinyloxyacetic acid, butoxyethyl	Diesel Oil	32 oz./96 oz.
Roundup Pro (Monsanto Co.)	Glyphosate, N-(phosphonomethyl)glycine, in the form of its isopropylamine salt	None	100%
Stalker (BASF Corp.)	Isopropylamine salt of Imazapyr (2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-3-pyridinecarboxylic acid)	Diesel Oil	10 oz./1 gallon
Tordon RTU (DOW AgroSciences)	Picloram: 4-amino-3,5,6-trichloropicolinic acid, triisopropanolamine salt	None	100%
	2,4-dichlorophenoxyacetic acid, triisopropanolamine salt		

Evaluation Methods

Six months after treatment, in late May 2005, treated shrubs were relocated and evaluated. Impact of treatment was evaluated by qualitatively assigning a number of 0-4 to the treated stem with 0 indicating no sign of regrowth (no sign of new leaves or shoots), 1 indicating 1/4 of the stem showed growth, 2 indicating 1/2 of the stem showed growth, 3 indicating 3/4 or most of the stem showed growth and 4 indicating all of the stem showed apparent growth, with no detrimental effect observed. Efficacy of each treatment was also recorded for multiple-stemmed shrubs by applying the same qualitative scale to each stem of the shrub. By this means, we hoped to determine whether a treatment of a single stem could eradicate an entire multi-stemmed shrub.

Statistical Analysis

We performed MANOVAs using herbicide, application method, dbh (diameter at breast height) of the treated stem, and number of stems per shrub as factors. Analyses were performed for each of three dependent variables: (1) regrowth of the treated stem (STEM1), (2) mean regrowth of non-treated stems of the same shrub as the treated stem (STEMEXT), and (3) mean regrowth of all stems of the same shrub (STEMALL). For MANOVAs, we placed dbh into two categories: "small" (dbh = 3-5 cm) and "large" (dbh >5 cm). We also placed number of stems into two categories within a variable STEMCAT: "single" (no. of stems = 1) and "multiple" (no. of stems >1). All possible interactions between factors were examined, and only significant results are reported. To compare significance within treatments of herbicide and application, we also performed one-way ANOVAs. All probabilities were Bonferroni-adjusted. SYSTAT v.9 (SPSS 1998) was used for all analyses.

RESULTS

We were able to score 313 shrubs for six herbicide treatments [Brushmaster, Garlon 4, Roundup, Stalker, Tordon, and none (herbicide control)] and four application treatments [basal bark, cut stump, girdling, and none (application control)] (Table 2). The mean dbh of treated stems was 5.47 cm (range 3-15), and the mean number of stems per shrub was 1.77 (range 1-9). There were 181 small (3-5 cm dbh) primary stems and 132 large (>5 cm dbh) primary stems. There were 182 single-stemmed shrubs and 131 multiple-stemmed shrubs. Control plants were evaluated to have a mean score of 3.81.

Means and standard errors of treatments are shown Figures1-3. The MANOVA performed for STEM1 was significant (n = 313, F-ratio = 6.941, $P < 0.0005$, multiple $R^2 = 0.637$). The effect HERBICIDE was significant (F-ratio = 7.131, $P < 0.0005$): Roundup, Stalker, and Tordon were each more effective than Garlon, Brushmaster, or no herbicide. However, in a separate ANOVA there were no significant differences between Roundup, Stalker, or Tordon (n = 120, F-ratio = 0.802, P = 0.451). APPLICATION (F-ratio = 8.573, $P < 0.0005$) was also significant: girdling and cut stump were more effective than basal bark or no application. However, in a separate ANOVA there was not (quite) any significant difference between girdling and cut stump (n = 120, F-ratio = 3.694, P = 0.057). The interaction HERBICIDE*APPLICATION was significant (F-ratio = 6.737, $P < 0.0005$), meaning some herbicides worked better with some application methods (Figure1).

Table 2. Treatments and final sample size.

Treatment	Shrubs
Brushmaster X Basal Bark	18
Brushmaster X Cut Stump	19
Brushmaster X Girdling	19
Garlon 4 X Cut Stump	20
Garlon 4 X Basal Bark	19
Garlon 4 X Girdling	20
Roundup Pro X Cut Stump	20
Roundup Pro X Girdling	20
Stalker X Basal Bark	19
Stalker X Cut Stump	20
Stalker X Girdling	19
Tordon RTU X Cut Stump	20
Tordon RTU X Girdling	21
Girdling Only	20
Cut Stump Only	19
Control	20

The MANOVA performed for STEMEXT was significant (n = 131, F-ratio = 3.416, $P < 0.0005$, multiple $R^2 = 0.547$). Again Roundup, Stalker, and Tordon were each more effective than Garlon, Brushmaster, or no herbicide (F-ratio = 5.110, P = 0.003), but there were no significant differences between Roundup, Stalker, or Tordon (n = 47, F-ratio = 0.683, P = 0.511).

The MANOVA performed for STEMALL was significant (n = 313, F-ratio = 6.670, $P < 0.0005$, multiple $R^2 = 0.628$). Again Roundup, Stalker, and Tordon were each more effective than Garlon, Brushmaster, or no herbicide (F-ratio = 14.596, $P < 0.0005$), but there were no significant differences between Roundup, Stalker, or Tordon (n = 120, F-ratio = 1.309, P = 0.274). APPLICATION (F-ratio = 6.792, P = 0.001) was again also significant: girdling and cut stump were significantly more effective than basal bark or no application, and again there were no significant differences between girdling and cut stump (n = 120, F-ratio = 0.880, P = 0.350). The interaction HERBICIDE*APPLICATION was significant (F-ratio = 7.199, $P < 0.0005$): some herbicides worked better with some application methods. The interaction APPLICATION*STEMCAT was also significant (F-ratio = 5.268, P = 0.002): girdling and cut stump applications worked better than basal bark or application controls on shrubs with multiple stems, regardless of dbh or which herbicide was used.

DISCUSSION

The results of our study indicate that *R. cathartica* can be effectively killed by a combination of cutting or girdling the plant and applying certain herbicides to the exposed area (Figures 1-3). Cutting and girdling used with these herbicides were about statistically equal in effectiveness.

Figure 1a.

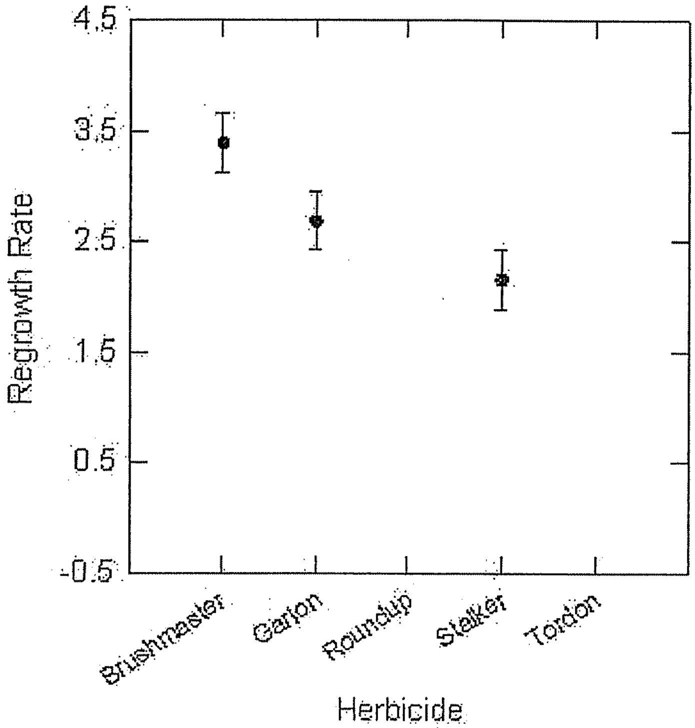


Figure 1c.

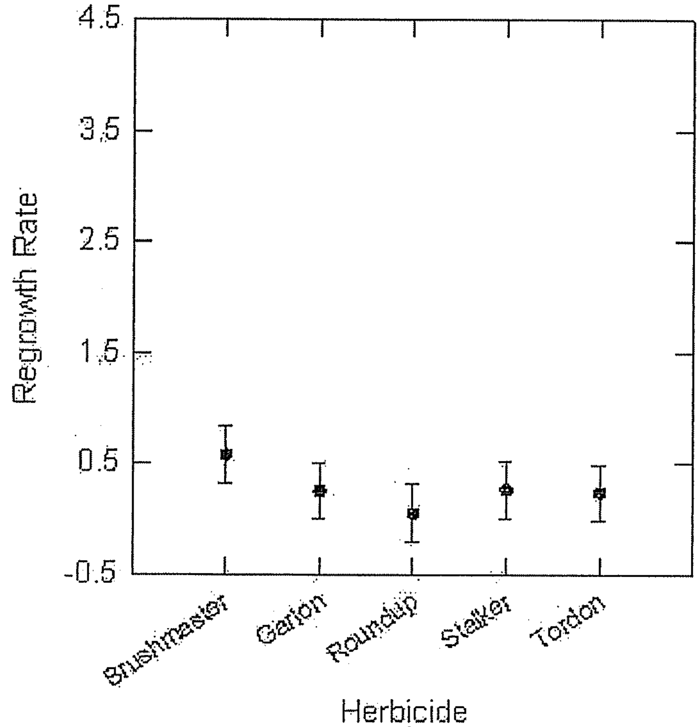
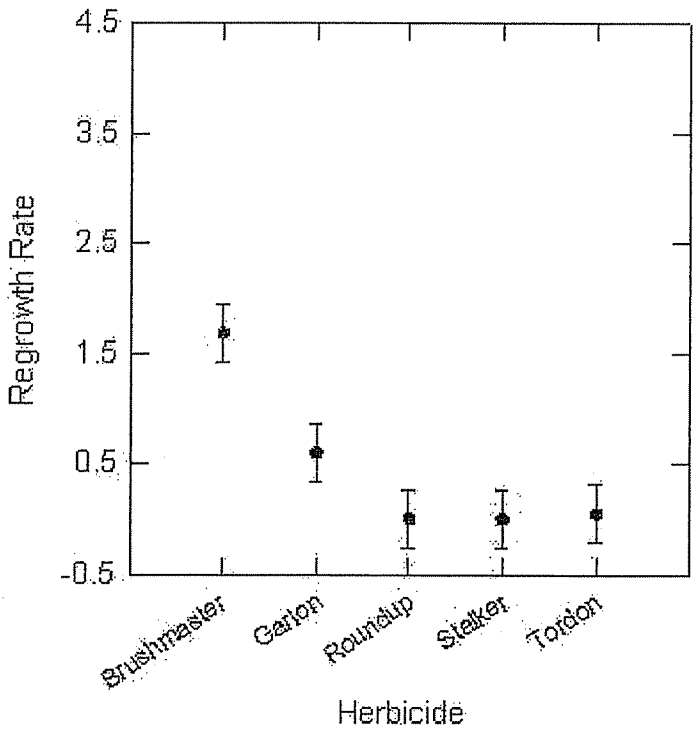
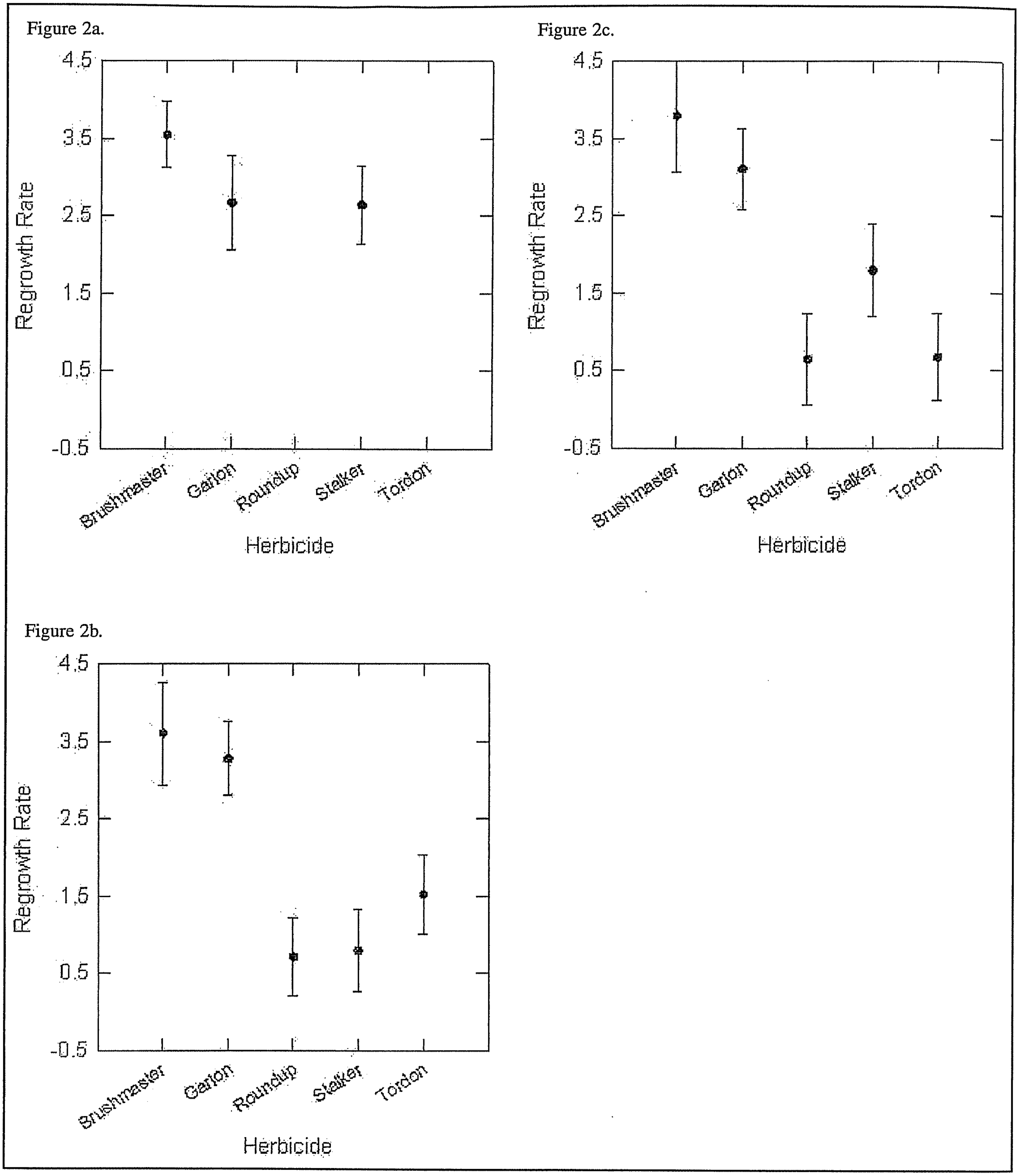


Figure 1b.



Figures 1a-1c. Effects of herbicide and application on treated stems only. *y*-axis values are regrowth rates on a 0-4 scale: the lower the value, the less the buckthorn survived, and the more effective the treatment. Figure 1a shows results of basal bark application, Figure 1b shows results of cut stump application, and Figure 1c shows results of girdling application. Two herbicides, Roundup and Tordon, are not recommended for basal bark application by the manufacturer and were not so used.



Figures 2a-2c. Effects of herbicide and application <u>on non-treated stems of multiple-stemmed shrubs only</u>. *y*-axis values are regrowth rates on a 0-4 scale: the lower the value, the less the buckthorn survived, and the more effective the treatment. Figure 2a shows results of basal bark application, Fig. 2b shows results of cut stump application, and Figure 2c shows results of girdling application. Two herbicides, Roundup and Tordon, are not recommended for basal bark application by the manufacturer and were not so used.

Figure 3a.

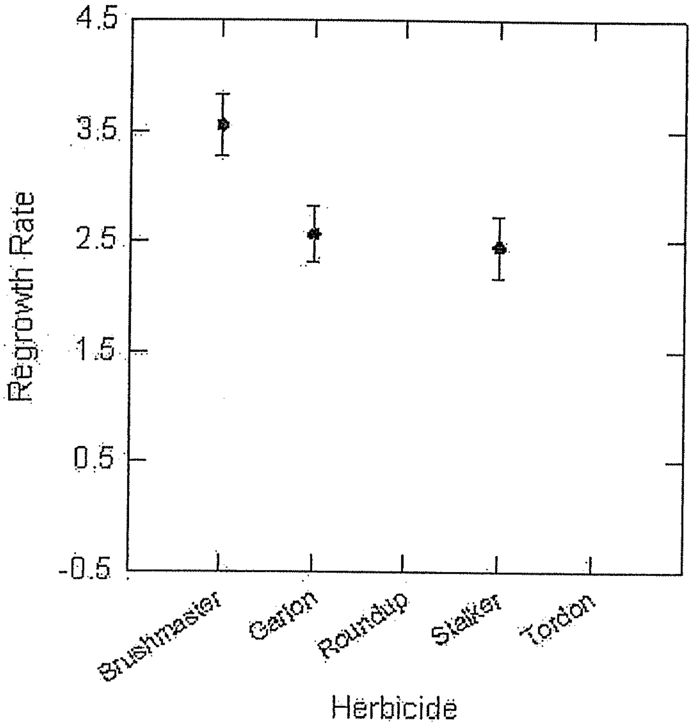


Figure 3c.

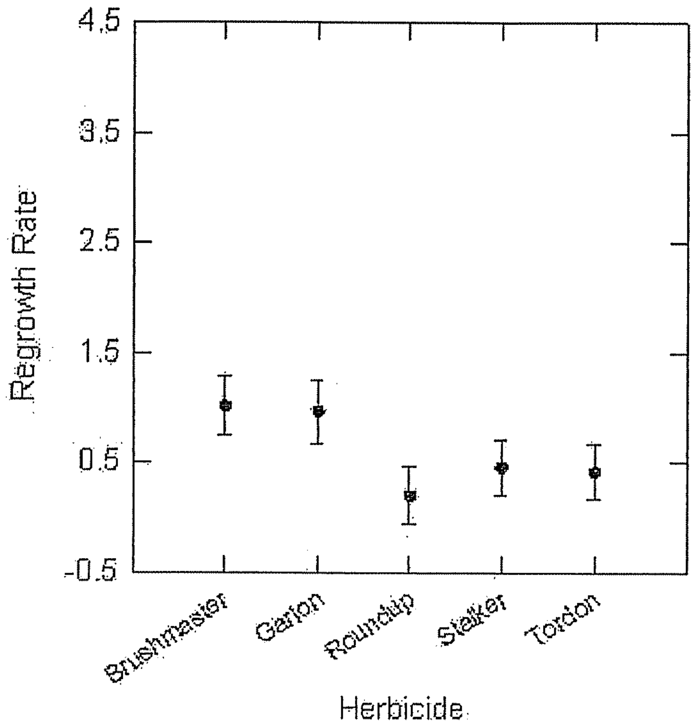
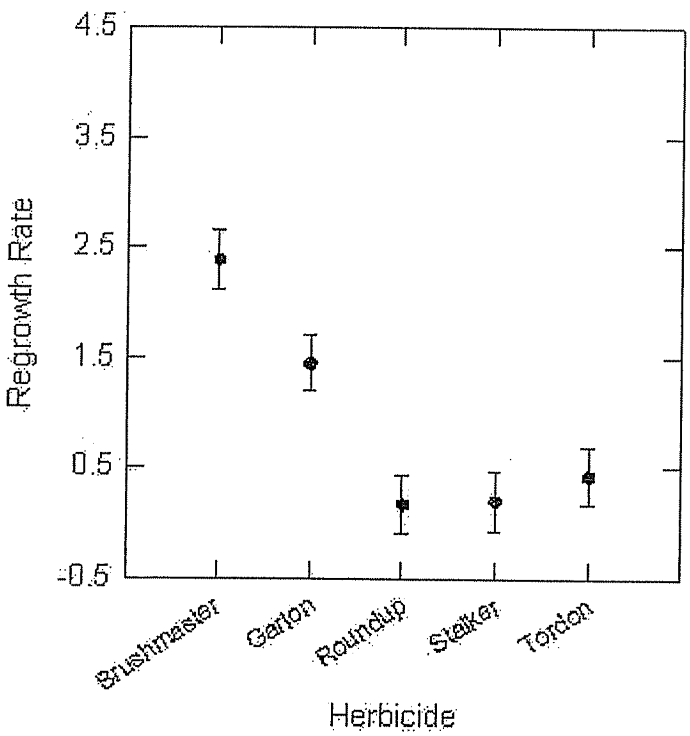


Figure 3b.



Figures 3a-3c. Effects of herbicide and application on all stems (cumulative of stems in Figures 3 & 4). *y*-axis values are regrowth rates on a 0-4 scale: the lower the value, the less the buckthorn survived, and the more effective the treatment. Fig. 3a shows results of basal bark application, Fig. 3b shows results of cut stump application, and Fig. 3c shows results of girdling application. Lines connect and identify the mean of each treatment result. Two herbicides, Roundup and Tordon, are not recommended for basal bark application by the manufacturer and were not so used.

When cutting or girdling without herbicide was used, we found (as have other studies) that shrubs developed new shoots from the base of the shrub (Figure 4). The use of herbicides with basal bark application was less effective than with girdling or cut stump application, resulting in greater regrowth of the shrub (Figures 1-3). Our data suggests that girdling or cutting along with the proper herbicide of a single stem of multiple-stemmed buckthorn usually results in the death of the entire shrub (Figures 2-3, 5). Given the potentially large savings of time and materials gained by treating only one stem, we feel that this is one of the most important results of this study.

The product labels for all five of the herbicides evaluated have a human risk rating of Caution, so these five herbicides are approximately equal in human safety. All herbicides required limited personal protective equipment: chemical resistant gloves and clothing that limits skin exposure.

Statistical analysis indicated that Roundup, Tordon, and Stalker were more effective than either Garlon 4 or Brushmaster (Figures 1-3). Roundup, Tordon RTU, and Stalker all present contamination risks to water, and manufacturers' instructions do not allow for application to water, use in wetland areas, or in areas below mean high water marks (DOW AgroSciences LLC 1997b, BASF Corp. 2000, Monsanto Co. 2001). The labels for both Tordon and Stalker indicate the herbicides readily seep or move through topsoil resulting in increased risk of ground water contamination or run off contamination of nearby water ways (DOW AgroSciences LLC 1997b, BASF Corp. 2000). However, the Roundup label identifies it as a compound with high soil affinity (Monsanto Co. 2001). Monsanto reports that Roundup is bound to soil particles making it unavailable to root uptake by neighboring foliage and reduces the likelihood that it can leech into ground water or run off into nearby water ways. Additionally, Monsanto states that the compound remains bound to soil particles until natural biological degradation is carried out under both aerobic and anaerobic processes by soil microflora. Relyea (2005) recently reported finding that Roundup was a significant hazard to amphibians, killing two species of tadpoles when directly applied to 1000-L pools of water. However, it must be repeated and emphasized that adding Roundup directly to water (or near bodies of water) is explicitly and repeatedly prohibited in Monsanto's label (Monsanto Co. 2001). Our opinion of relative herbicide environmental safety remains solely dictated by the manufacturers' labels, a comparison of which seems to recommend Roundup (DOW AgroSciences LLC 1997a,b; BASF Corp. 2000; Monsanto Co. 2001; PBI/Gordon Corp. 2003). Nevertheless, Relyea's findings emphasize the necessity to follow manufacturers' instructions and limit the use of any of these herbicides to dry areas only.

The final criteria we considered in our assessment were cost effectiveness and efficiency of application. All herbicidal applications required approximately equivalent amounts of time and effort for application; though Brushmaster, Garlon, and Stalker did require mixing with dilutants, whereas the versions of Roundup and Tordon that we used did not.

Prices per ounce of herbicide used were calculated using the number of ounces of diluted herbicide that can be made from the herbicide formulations we used and published prices from vendors or manufacturers of the herbicides. Costs of dilutants were included if applicable. The costs of the three most effective herbicides are Roundup = \$0.50/oz, Tordon = \$0.28/oz, and Stalker w/diesel oil dilutant = \$0.21/oz. Thus, Roundup was about twice as expensive as the other two most effective herbicides. However, the costs of the herbicides themselves are probably insignificant compared to the value of the labor used in applying them.

It should be noted that successful eradication of buckthorn might still require follow-up. In an experiment testing the results of removing glossy buckthorn (Rhamnus *frangula),* neither percent native herb cover nor native plant species richness were significantly increased by its removal in the two years following treatment, because plots where *R. frangula* was eradicated were found to have five-fold greater first-year *R. frangula* seedling density than other treatments (Frappier et al. 2004). However, after two years, first-year *R. frangula* seedling density was similarly low in all treatments. Control efforts for all *Rhamnus* may need to focus on conspecific seedling emergence for at least two years following eradication of the shrubs.

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Figure 4. Photo of shrub with new shoots from the base after girdling six months prior.

Figure 5. Photo of multiple-stemmed shrubs killed with girdling and Roundup Pro application to a single stem of each.

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