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Control of the Invasive Exotic *Rhamnus cathartica* in Temperate North American Forests

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Introduction

Common or European Buckthorn (*Rhamnus cathartica* L.) is a deciduous shrub, or small tree, of the Rhamnaceae family that readily invades woodland, savannah, and prairie habitats. An endemic of Eurasia, *R. cathartica* was introduced to North America as an ornamental shrub in the mid 1800s and was originally used for hedges, farm shelter belts, and wildlife habitat. It has spread extensively since and has a range currently bound by Nova Scotia, Canada in the northeast, Saskatchewan, Canada in the northwest, northeastern Kansas, USA in the southwest, and North Carolina, USA in the southeast (Meader 1999). Disturbed deciduous forest edges and open oak woodlands seem to be most susceptible to invasion by *R. cathartica*. Most alarming is the speed with which it is able to invade an area and displace native vegetation. The purpose of this paper is to provide an overview of *R. cathartica's* biology and life history, the ecosystem it is invading, and the various control methods currently being used by restoration practitioners to halt its invasion.

Biology

R. cathartica grows from two to eight meters tall (six to 25 feet) (Figure 1) (MNDNR 2000). It has an irregular spreading crown and a dark gray to brownish rough, scaly bark at maturity. Leaves are usually opposite, elliptic or oblong shaped with fine, round toothed or nearly smooth margins and dark green on the upper side contrasting with a lighter green underside (Samuels 1996). The three to four main branching veins on each side of the midrib that strongly curve or arch forward towards the tip of the leaf are one of the more recognizable morphological features (Figure 2) (OVMA 2000). Identification of *R. cathartica* is especially easy by the end of the growing season as the leaves persist on the branch well into early winter, maintaining a dark green appearance even after several frosts (Meader 1999). The tips of branches as well as branch forks are typically spiked with spines ranging from 0.5 cm to 5.5 cm (Figure 3) (Zomlefer 1994). *R. cathartica* is dioecious. In the spring, small (1.5-2.5 mm), greenish-yellow, four-lobed flowers emerge. Staminate (male) flowers grow in clusters of two to eight flowers with four stamens in each flower. Carpellate (female) inflorescence usually lack petals and grow in clusters of two to 15 flowers (USGS 2000).

Beginning around five years of age, *R. cathartica* is capable of producing fruit classified as drupes (Archibold et al. 1997). Fruit develop in early summer and mature in mid to late fall. Each drupe typically contains four hard, round seeds and turn from green to dark purple to black at maturity. The seeds and fruit are considered poisonous to humans and other animals. If eaten, the drupes cause severe stomach cramps (Converse 1985). Although *R. catharica* is capable of asexual reproduction, its primary means of reproducing is via seed.

Figure 1. Five meter tall mature male *R. cathartica* tree (foreground and center) with foliage still persisting on branches after three weeks of consistent freezing temperatures (all photos in this report were taken Nov. 27, 2000 in south Minneapolis, MN near Minnehaha Creek).

Figure 2. Senescing *R. cathartica* leaves. Notice characteristic arching pattern of the main branching veins.

Figure 3. Lateral spikes along the length of a young branch stand out against the brown, scaly bark background of the trunk.

Life History

Once the production of fruit has begun, the inevitable profusion of progeny is nearly impossible to control as the seeds are readily dispersed in a number of ways and remain viable for several years. Many of the fruit drop below the parent plant and germinate within the immediate vicinity. Some fruit are washed away with heavy rains and germinate where they settle (Gill and Howell 1984). *R. cathartica* fruit have been known to float for 3-6 days before sinking (TNC 1995). Insects, birds, and small mammals, such as, voles, mice and other rodents, are also potential vectors (USGS 2000).

In particular, avian dispersion of seed greatly enhances the invasiveness of *R. cathartica*. Studies show that the majority of seed dispersed from a parent tree may be attributed to birds (Haber 1998). Several bird species, such as American robins, European starlings, blue jays, and cedar waxwings eat the drupes off mature trees when alternative food sources are depleted (Gourley and Howell 1984). According to several studies, most birds do not prefer *R. cathartica* drupes as they contain harsh unpalatable chemicals (Maw 1981). However, by late fall avian consumption of the fruit becomes increasingly common (Haber 1998, Rebuffoni 1997). Relatively few of the ingested seeds are destroyed in the digestive tract of the animals while the rest are carried away and redistributed intact (Howland 1996). The chemical compound found in the drupe mesocarp that is responsible for inducing the laxative effect is anthraquinone (Archibold et al. 1997).

Quick passage of *R. cathartica* seed through the digestive tracts of animals is the result. Research also suggests that the seeds germinate more quickly after the fleshy fruit has experienced a degree of digestion (Gourley and Howell 1984). Interestingly, a study examining the effect of exotic shrub species on songbird nest predation found that American robins preferably nested in *R. cathartica* and also experienced a significantly higher daily mortality rate than those nesting in *Crataegus* sp., a native shrub species (Schmidt and Whelan 1999). This study suggests that, ironically, a native bird species appears to

be enhancing the invasive capabilities of *R. cathartica*, which in turn serves as an ecological trap for the birds.

An extended growing season likely gives *R. cathartica* a competitive advantage over native plant species as well. Harrington et al. (1989) showed that *R. cathartica's* leaves remain on the tree an average of 58 days longer than its native counterparts, *Cornus racemosa* and *Prunus serotina*. Its leaves emerge earlier and senesce later. In both cases, upper canopy foliage is largely absent. Consequently, photosynthesis under high light availability conditions is significantly greater for *R. cathartica* than for native shrub species. Indeed, 27 to 35 percent of *R. cathartica's* annual carbon gain occurs before *C. racemosa* leaf emergence (Harrington et al. 1989).

Allelopathy may also contribute to *R. cathartica* invasiveness. Some observations indicate that *R. cathartica* possesses allelopathic chemicals within the fruit and leaf structures (Boudreau and Wilson 1992). Allelopathic chemicals act as a germination or growth inhibitor to other organisms that could potentially occupy the affected area. The presence of these chemicals improves *R. cathartica's* chance of survival by eliminating some or all of its competition. Preliminary studies by Krebach and Wilson (1996) suggest that the flesh of the drupes contain terpenoids or alkaloids which are capable of retarding the growth of competing plants. The extent to which *R. cathartica's* release of allelopathic chemicals to the soil accounts for native plant displacement has yet to be determined. A greenhouse experiment measuring the fitness of native species grown in soils varying in allelopathic chemical content would help to illuminate the degree to which allelopathy contributes to *R. cathartica's* competitive superiority.

Ecosystem Affected

R. cathartica seems to do best in well-lit, well-drained areas, but is tolerant of a broad range of soil types (neutral to alkaline, sandy or clayey soils) and light conditions (TNC 1995). Across its range, *R. cathartica* is a particularly problematic invasive of deciduous forest communities. For example, the eastern deciduous forest community, found throughout much of the American portion of its range, has experienced extensive invasion. Some eastern deciduous forest tree species include *Quercus alba, Q. rubra, Q. macrocarpa, Acer saccharum, Tilia americana, Ulmus americana, Fraxinus pennsylvanica, Celtis occidentalis, Juglans nigra, Carya cordiformis,* and many others (Gleason and Cronquist 1963). By reducing recruitment of the above tree species and crowding out the native herbaceous species found in the understory (e.g., *Thalictrum dioicum, T. dasycarpum, Sanguineria canadensis, Trillium grandiflorum, Maiaenthemum canadense, Trientalis borealis, Uvularia grandiflora, Polygonatum commutatum*), *R. cathartica* has altered in a short period of time the vegetation composition of those forest communities it has invaded. Besides the primary concern for the degradation of natural areas and urban landscapes, *R. cathartica* poses an additional threat when proximate to agricultural fields. It is the alternate host of the crown rust fungus, *Puccinia coronata,* which, under wet conditions, can severely reduce oat field yields (Munkvold 1996).

Control Methods

Due to its prolific nature, *R. cathartica* is a difficult exotic species to eradicate. Several types of control are currently being used and tested in areas affected. They include mechanical, physical (use of fire), and chemical methods of control. There is no clear consensus on the most effective means of control, but herbicide application to a newly cut stump seems to be an emerging preference. These methods must often be employed repetitively because of *R. cathartica's* persistent re-sprouting ability. The capacity for extended dormancy in *R. cathartica* seeds, an average of 6 years, also necessitates the use of repetitive treatments (Archibold et al. 1997). In most restoration efforts, a combination of at least two of these methods is utilized.

Mechanical

The most environmental friendly and time-consuming method of *R. cathartica* removal is via mechanical means (MNDNR 2000). If resources are limited, initial efforts should be concentrated on removing the female, or fruit producing, trees. This will at least minimize addition to the existing seed bank, thus reducing the amount of time spent in the future on seedling removal. Removal of trees with a base diameter of up to seven cm can be accomplished with commercially available jaw-type pullers known as "weed wrenches" or "broom pulls" (Ness 1989). Those individuals with a base diameter larger than seven cm will likely have to be cut with a chain saw or hand saw and the remaining stump dug out with a shovel. If the stump is left in the ground then subsequent visits to remove any re-sprouting will be necessary.

Seedlings that are less than 1 meter (m) tall can usually be pulled by hand. Pulling trees up from the roots will prevent them from re-sprouting and avoid the need for further treatment. Hand pulling is most effective immediately after significant rainfall when the ground is well saturated. Wet soil allows for most of the root to be removed with minimum effort (Rebuffoni 1992). Safety measures should always be taken to avoid injury when removing the trees. Experts advise using safety goggles and thick work gloves to protect against the thorns (Rebuffoni 1997).

In areas where there are large numbers of seedlings, mowing can reduce plant number and vigor (USGS 2000). Mowing is done in early June and late August for three consecutive years and usually results in a reduction in stem height and numbers. Unfortunately, mowing can also impair the development of native forb species as well. In addition, mowing will not remove *R. cathartica* from the area; it will only keep populations under control and prevent the trees from producing fruit.

Any time fruit bearing trees are cut after the fruit has ripened, the seeds should be removed from the branches and destroyed. Fruit that is allowed to remain on the tree has the potential to be eaten by animals or drop and sprout. Burning or simply putting the seeds in a sealed trash bag can remove potential buckthorn from the system. Specific instances of composting being used as a means of fruit disposal were not found for this paper, but it would probably be a good idea to try this method and place some of the resulting compost in gardening trays or pots to see if any *R. cathartica* seedlings are produced.

Physical

Prescribed or controlled burning is used to eradicate populations of *R.cathartica* in areas adapted to fire (Kline 1981). Areas that are suited to fire management are those that contain fire tolerant natives (e.g., older *Quercus rubra* and *Q. macrocarpa* with thick, fire retardant bark) have well-drained soils, and have enough litter under the trees to fuel the fire. A successful burn consumes the brushy understory, leaving the ground mostly bare with the larger fire resistant trees left intact. Controlled burns usually have the biggest impact on *R. cathartica* seedlings and the current year's seeds. The best time to conduct burns is between late March and early May as low carbohydrate levels should reduce re-sprouting vigor (Dziuk 1998). Considering the time, energy, and safety considerations involved, it is usually only larger restorations relatively far away from human habitation that employ fire to control *R. cathartica* (Moriarty 2000). One impediment to conducting a burn is that *R. cathartica* usually shades out understory species, reducing the amount of leaf litter found in the area and consequently limiting the ability to employ fire as an effective means of control (Dziuk 1998). A sufficient accumulation of dead plant material is necessary to move the fire from one place to another.

Chemical

There is much information available about herbicides that are often used to impair the growth and development of *R. cathartica*. Restoration practitioners and interested members of the public should carefully read all manufacturers' directions prior to using a herbicide and use proper safety equipment during application. The best time of year to use herbicides on target plants is just after the native grasses and wildflowers have gone dormant (Boudreau and Wilson 1992). Herbicide applications may be done early in the season just after the trees have leafed out and before the trees have begun to bud, but those conducted in the fall or early winter appear to be the most effective (Aho 2000, Bohnen 2000, Solecki 1997). Applications conducted at temperatures below zero degrees Celsius (32 degrees Fahrenheit) will likely experience reduced effectiveness (Solecki 1997). Many of these chemicals such as Garlon and Roundup are unrestricted in their usage and can be purchased without a special license (Apfelbaum 1984). Table 1 is a list of the most thoroughly tested and commonly used herbicides available along with their potential impact on the surrounding environment.

Contol Method Efficacy

There is no clear consensus on the most effective means of control, but the application of herbicides to newly cut stumps seems to be an emerging preference. Conversations with several local restoration practitioners add further insight into the usage of herbicides. Mike Aho, a naturalist at Sibley State Park (located 150 km northwest of Minneapolis, MN near the town of New London), has found basal bark and cut stump application of Garlon 4 to be a reliable means of controlling *R. cathartica* (Aho 2000). Brush application in the fall, as opposed to spraying, resulted in no non-target plant mortality. In the initial phase of eliminating the mature trees capable of reproduction, chemical application to stumps yielded 100 percent mortality while basal bark treatment yielded slightly less efficacy. Some of the trees with a basal diameter greater than seven cm did not fully succumb until the second year after application. Garlon 3A, Tordon RTU, and Roundup have also been used by Aho in the past. Despite the high efficacy achieved, Garlon 3A has greater persistence because of its amine salt component in the environment and the higher user risk. In addition, painful blistering immediately ensues following contact with even a drop of the solution. Aho found application of Tordon RTU to stumps in the winter produced good results as well. So although year round usage is an advantage, Tordon's potential as a major groundwater contaminant renders it less desirable (Dziuk 1998). His use of Roundup yielded the least reliable results. Some stumps that received an application of the manufacturer recommended medium strength (30-50 percent) solution managed to re-sprout.

Field results obtained by Julia Bohnen, a University of Minnesota Landscape Arboretum restoration manager, contradict those found above (the arboretum is located in Chanhassen, MN, about 30 km west of Minneapolis). Bohnen (2000) achieved excellent results with late summer to early winter applications of 50 percent strength Roundup to cut stumps. Late summer to early winter treatment with a basic utility-grade spray bottle, available at any hardware store, succeeded in confining the application to *R. cathartica* and limiting non-target plant mortality. Achieving desired results with a herbicide that is relatively harmless to the environment is indeed attractive. She has also used the foliar treatment herbicide, Krenite S, to control seedlings and young saplings and, similar to results obtained by other practitioners, achieved a very low efficacy.

Likewise John Moriarty, currently a restoration manager for Ramsey County Parks in St. Paul, MN, has also observed low efficacy of Krenite S. Its past use in a secondary herbicide application at Highland Park in Bloomington, MN, a southern suburb of Minneapolis, proved totally ineffective (Moriarty 2000). Regarding Roundup, Moriarty has also found it to be a less reliable means of control, especially at lower

strengths. Instead he highly recommends the use of Garlon 3A, or more specifically its weaker commercial version, Brush-B-Gon.

The effectiveness of prescribed burns in controlling *R. cathartica* is more difficult to determine at this point because of the greater amount of time it takes to realize results and its rather recent advent. A study conducted in 1998 indicated that fire reduced the number and vitality of *R. cathartica* in a given area (MNDNR 2000). In another study, small seedlings (less than 25.5 cm tall) with shallow roots were particularly impacted by fire (Boudreau and Wilson 1992). Aho (2000) reports a high *R. cathartica* seedling mortality rate after three consecutive years of conducting prescribed burns. Similarly, Moriarty (2000) has had success with the several burns he has conducted and especially believes in fire as an essential means of controlling the accelerated growth of seedlings that normally ensues after removal of the more mature individuals. To the contrary, a 1988 study on fire and *R. cathartica* control showed that *R. cathartica* populations were virtually unaffected when surveyed the following spring (TNC 1995). The study concluded that *R. cathartica's* ability to re-sprout after top killing was not diminished even after several burns. Furthermore, newly burned areas may serve as a temporary window providing prime conditions for invasion by nearby *R. cathartica* and dormant seed germination resulting in a re-infestation worse than the original (USGS 2000).

Despite being labor and time intensive, mechanical means of controlling *R. cathartica* are often of necessity when a large number of seedlings is interspersed by desirable vegetation. Under these conditions herbicide treatment is prohibitive. Larger trees can be removed mechanically too. Bohnen (2000), in her restoration efforts, has had success removing all age classes, up to 7 cm in diameter, by sufficiently loosening their roots with a shovel followed by hand pulling/pushing. The recruitment of volunteer help , such as 'sentenced-to-serve' crews (those who must perform community service as a means of satisfying their sentence for a minor crime), has made mechanical control methods a more viable option for larger restoration efforts (Hayman 2000).

Control Strategy

Current efforts on parklands to control *R. cathartica* are a good start, but the efficient avian dispersal of *R. cathartica* propagules necessitates the assumption of a regional removal stategy. To reduce the threat of immediate reinfestation of a given park, residential areas within close proximity to that park should be cleared of mature *R. cathartica* as well. Education efforts that would succeed in mobilizing the public to remove *R. cathartica* from their properties, or infested areas within their immediate vicinity, should be highly encouraged.

The importance of residential control may be further emphasized by an example of *R. cathartica* infestation of urban parkland along Minnehaha Creek approximately 0.5km from my south Minneapolis residence. An individual adult *R. cathartica* tree laden with fruit and a *R. cathartica* hedgerow, also bearing fruit, exist in neighboring yards (Figures 4a and 4b). Five city blocks away, the woodland buffering the creek is experiencing varying states of *R. cathartica* infestation. Its density is quite heavy in spots. The understory of a 30 m patch of mature native tree species (*Populus deltoides*, *Fraxinus* sp., *Ulmus* sp., and *Acer negundo*) completely choked with a near singular age class of two to three m tall *R. cathartica* dramatically demonstrates one such instance (Figure 5). Several large, fruit bearing trees within a short distance of the patch are the likely propagule sources. Their removal should be conducted immediately, but unless the mature *R. cathartica* capable of producing fruit in the nearby residential area are removed, a successfully restored portion of the park may once again be faced with *R. cathartica* encroachment. A greater dissemination of a list of alternative native shrubs that could serve as replacement plantings would likely expedite public involvement in residential control. Possible native shrub replacements for Minnesota are *Aronia melanocarpa* (Michx.) Ell., *Alnus incana* (L.) subsp. *rugusa*

(Du Roi) Clausen, *Amelanchier* sp., *Cornus* sp., *Corylus americana* L., *Hamamelis virginiana* L., *Symphoricarpos albus* (L.) Blake, *Viburnum lentago* L., *V. rafinesquianum* Schultes, and *V. trilobum* (Marsh.) (Moriarty 2000).

Figures 4a and 4b. Clusters of fruit are apparent on this mature, female *R. cathartica* tree (a) and hedgerow (b).

a

b

Figure 5. Stand of mature native tree species with a thick *R. cathartica* understory.

Conclusion

As extensive as the invasion of temperate forest communities by *R. cathartica* has been, it is clear that management techniques currently being employed by restoration practitioners and private citizens are capable of halting its further encroachment. The case of *R. cathartica's* invasion of native habitat is a testimony to the importance of addressing an exotic species in its initial stages of introduction, not after it has become well established. Much time and money can be saved. The potential for *R. cathartica* to significantly alter native plant community structure and function demands a concerted response. Accordingly, a combination of increased public awareness and greater allocation of funds are critical to the expansion of current restoration efforts. The future ecological integrity of temperate North American forests depends on it.

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Table 1. Commonly used herbicides. Information provided by MNDNR 2000.

Product Name	Active Ingredient	Strength*	Comments
Roundup	Glyphosate	18-100%	Nonselective. Will kill any vegetation it contacts. Immediate application to cut stump (within 24 hours) is necessary. Dilute with water. Practitioners have reported variable efficacy at manufacturer recommended dilutions (30-50% strength). Glyphosate degrades easily and is relatively harmless to the environment. Very little risk to user. Late fall application, when most other plants have gone dormant, assures negligible impact on non-target plants.
Garlon 3A	Triclopyr (44.4% amine salt)	8-100%	Applied to cut stumps. Dilute with water. Negligible impact on surrounding vegetation. User risk is significant. Must wear protective eye gear. Cost effective if applied to large acreage. High efficacy. The homeowner's version, Ortho's "Brush-B-Gon", is an 8% strength solution.
Garlon 4	Triclopyr (61.6% ester)	12.5% early in growing season, otherwise 20%.	Good for basal bark or cut stump application. In the former case, entire circumference of basal 10 inches (25.5cm) should be covered via low pressure sprayer or brush. High efficacy. Recommended solution strengths are achieved via dilution with diesel fuel. Does not have same user risks as Garlon 3A. Hot summer weather may volatilize ester component and consequently impact non-target plants. Fuel would likely impact nearby plants as well.
Tordon RTU	Picloram and 2,4-D	Follow product directions	Ready to use--no mixing required. Winter application to cut stump yields high efficacy. Application with a non-foam brush is recommended. Relatively inexpensive, but moves readily through soil and kills non-target vegetation.

Trimec	2,4-D	50%	Affects broadleaf plants. Dilute with equal portion of water. Can also be mixed with diesel fuel at 12.5% solution in early season. Like Tordon, easily moves through the soil and is prone to adversely impacting non-target vegetation.
Krenite S	Fosamine	Follow product directions	Affects woody plants. Should be sprayed on foliage in late fall when other plants are dormant. Inhibits bud break the following growing season. In practice, has proven to have very low efficacy. Necessity of complete coverage of target vegetation likely limits its efficacy. Timing of application may also be problematic

*Strength refers to that of the product and not the active ingredient.