Fact Sheets for Reforestation Strategies under Deer Pressure

by Ross Whitehead

under the supervision of Professor Lea Johnson
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Contents

Deer Repellents

Deer repellents are an unobtrusive and relatively effective method of protecting vulnerable plant species from damage due to browsing. Research has shown that some deer repellents can provide good protection for vulnerable tree species, but usually fail to exclude deer browse entirely, and can vary greatly in effectiveness (Ward and Williams 2010; Lemieux, Maynard, and Johnson 2000).

Table 1: A comparison of some repellents tested for effectiveness in reducing deer browse on yews. The protection index is relative to total deer exclusion by physical fences. Fencing served as a positive control and no repellent or protection served as a negative control (Ward and Williams 2010).

Commercial Repellent	**Active ingredient(s)**	**Application rate**	**Protection Index (%)**
Bobbex	Putrescent eggs Garlic oil Clove oil Fish meal Fish oil Meat meal	Once/10-14 days	93
Hinder	Ammonium soaps of fatty acids	Once/10-14 days	83
Liquid fence	Putrefied eggs Garlic Sodium Lauryl Sulfate	Once/day for 1 week, then monthly	78
Plantskydd	Dried blood	Once/6 months	60
Deer exclusion fence	-	-	100
No repellent	-	-	49

A comparison of deer repellents by Trent, Nolte, and Wagner (2001) suggest that repellents containing sulfuric compounds, such as those produced by putrefied eggs, provide the most effective means of controlling deer browse, as they are thought to mimic sulfuric compounds in the urine of deer predators. Repellents may not fully eliminate deer browse damage, and success of deer repellents may vary based on factors such as the availability of alternate forage.

Costs: Costs of deer repellents tend to correspond to the effectiveness of the repellent, with the most effective commercially available concentrates often being the most expensive. Desired frequency of application influences cost, as the most effective repellents require re-application every 1–2 weeks. Repellants may not provide protection in areas of heavy deer browse intensity, and may have an offensive odor when first applied, but do not affect the visual appearance of the plant.

Tree Shelters

Tree shelters are protective structures used to physically exclude trees from deer herbivory, and greatly improve survival of many sensitive species. Studies of tree shelter efficacy in reforestation generally find a significant improvement in growth rate and survivorship in areas of heavy deer browse, and strategies for improving tree seedling growth that are normally ineffective, such as weed management, improve growth and/or survivorship when implemented with tree shelters (Stange and Shea 1998; Sweeney, Czapka, and Yerkes 2002).

Table 2: A comparison of tree shelter studies and differences in survivorship between tree growth with and without shelters.

Study	Location	Duration of study	Survivorship without shelters	Survivorship with shelters
(Stange and Shea 1998)	Minnesota	2 years	65.6%	96.8%
(Sweeney, Czapka, and Yerkes 2002)	Maryland	4 years	12.1%	49.0%
(Dubois et al. 2000)	Alabama	2 years	70.0%	88.8%

Survivorship rates can vary widely based on environmental conditions, tree species, browsing pressure, and co-treatments. In particular, weed suppression strategies were often employed alongside tree shelters to reduce competition and improve growth, although these methods had little benefit when used without tree shelters, and occasionally increased mortality, possibly through increased seedling exposure to herbivory (Dubois et al. 2000; Stange and Shea 1998; Sweeney, Czapka, and Yerkes 2002).

When implementing certain types of tree shelters, it is important to consider the surrounding environmental characteristics and how the shelters might affect seedling growth. In particular, tube tree shelters, which block a portion of the light young trees are exposed to, were found to reduce growth in areas with high surrounding vegetation that blocked significant amounts of light, but improved growth where trees were exposed to high light levels (Laliberté, Bouchard, and Cogliastro 2008).

Costs: Installing tree shelters can typically cost $4.35 or more per seedling, based on a planting rate of 250 new trees per hectare (Dubois et al. 2000), but once installed are very low maintenance, although results can be improved through weed suppression through herbicide or mowing. The protection they provide is effective in areas of heavy deer browse.

Facilitative Plantings

Planting species that are less palatable to deer, alongside desirable species more palatable to deer, has the potential to reduce browsing damage to the desirable, highly palatable species. A meta-analysis of literature examining the increased survival of plants growing in association with unpalatable plants shows scientific support for the "repellent plant hypothesis," which proposes that less palatable plants drive away herbivores and increase the survival of more palatable neighboring plants (Ruttan and Lortie 2015).

For example, in a study of deer grazing patterns, plants in patches of high quality forage were browsed more often than plants in areas of low quality forage (Bee et al. 2009). The results of this study suggest that deer herbivory is influenced by the overall palatability of plants within the landscape, and that incorporating less palatable plants into landscape design and reforestation efforts may mitigate the effects of deer browse.

A study of the facilitative effect of less palatable plants found that the less palatable species increased the diversity of the community under significant grazing pressure, but actually reduced plant community diversity in the absence of grazing pressure compared to areas where both herbivory and the less palatable species were present (Callaway et al. 2005). This suggests that facilitative plantings of less palatable species may function as “nurseries” for more palatable, highly desirable species. This contextual support is reinforced by studies such as (Smit et al. 2007), but also show that under very high herbivory pressure, the effectiveness of facilitative plantings may be compromised as deer begin to browse less palatable species. Thus, under moderate herbivory, facilitative plantings may improve the survival of highly palatable species; it may not be necessary under low herbivory pressure, and under high pressure, it may not be effective.

Costs: The cost of facilitative planting can vary based on the cost of available plant material, but provides a low maintenance method of increasing the survival of more-palatable species in areas of moderate deer browse.

Deer Fencing

The exclusion of deer from an area by using relatively tall fencing material can protect large areas of habitat from high intensity deer browsing by almost entirely preventing access by white tailed deer. Deer fencing can function directly as a method of long-term passive restoration, as well as a short-term method to protect restoration projects from deer browse.

A study of long term deer fencing showed a significant change the plant community after 17 years of deer exclusion (White 2012). Additionally, a 10-year experimental study of deer exclusion found that increasing density of deer populations strongly corresponded to a significant reduction in stem density for deer-sensitive species, and a larger stem density for deer-tolerant species, such as ferns and black cherry (Horsley, Stout, and De Calesta 2003). The benefit to browse-sensitive species was also demonstrated by a four-year study of deer exclosures that showed reduced mortality of planted white cedar seedlings when compared to seedlings planted in unfenced areas (Palik et al. 2015).

Costs: Costs of deer fencing increase with the perimeter of the area needed to be fenced, and typical deer fencing costs can run between $4.50 and $7.50 per foot (Slifer, Grande, and Katz 2010). Additionally, fencing is not 100 percent effective at excluding all deer, and further effort may be required to remove deer who gain access. Additional techniques may be required to reduce damage from other herbivores that can bypass the fence.

Table 3: A summary of studies on the outcome of deer exclusion studies

Study	Duration	Results
(Horsley, Stout, and De Calesta 2003)	10 years	Under experimental deer densities within deer enclosures, low deer density favored the growth of deer-sensitive species, such as pin cherry, while high deer density favored the grown of less sensitive species, such as black cherry.
(White 2012)	17 years	Deer exclosures had higher levels of productivity, and experienced a two-fold increase in biomass. Species previously suppressed by deer browse, including white cedar and white pine, experienced increases in recruitment. Less palatable species typically consumed when deer are experiencing starvation, such as white spruce, also experienced increases in recruitment in fenced areas, suggesting very high intensity deer browse outside of exclosures.
(Palik et al. 2015)	4 years	Higher survival of browse-sensitive white cedar in protected areas, with 60% of seedlings surviving outside of fenced areas and 75% surviving within fenced areas. Relative stem diameter growth nearly doubled when white cedar was protected from deer browse (0.13 vs. 0.20), but less sensitive balsam fir had no significant increase in relative growth.

Bibliography

Bee, Jennie N., Andrew J. Tanentzap, William G. Lee, Roger B. Lavers, Alan F. Mark, James A. Mills, and David A. Coomes. 2009. “The Benefits of Being in a Bad Neighbourhood: Plant Community Composition Influences Red Deer Foraging Decisions.” *Oikos* 118 (1): 18–24. doi:10.1111/j.1600-0706.2008.16756.x.

Callaway, Ragan M., David Kikodze, Marina Chiboshvili, and Liana Khetsuriani. 2005. “Unpalatable Plants Protect Neighbors From Grazing and Increase Plant Community Diversity” 86 (7): 1856–62.

Dubois, M. R., A. H. Chappelka, E. Robbins, G. Somers, and K. Baker. 2000. “Tree Shelters and Weed Control: Effects on Protection, Survival and Growth of Cherrybark Oak Seedlings Planted on a Cutover Site.” *New Forests* 20 (2): 105–18. doi:10.1023/A:1006704016209.

Horsley, S. B., S. L. Stout, and D. S. De Calesta. 2003. “White-Tailed Deer Impact on the Vegetation Dynamics of a Northern Hardwood Forest.” *Ecological Applications* 13 (1): 98–118.

Laliberté, Etienne, André Bouchard, and Alain Cogliastro. 2008. “Optimizing Hardwood Reforestation in Old Fields: The Effects of Treeshelters and Environmental Factors on Tree Seedling Growth and Physiology.” *Restoration Ecology* 16 (2): 270–80. doi:10.1111/j.1526-100X.2007.00270.x.

Lemieux, Nicole C, Brian K Maynard, and William A Johnson. 2000. “Evaluation of Commercial Deer Repellents on Ornamentals in Nurseries.” *Journal of Environmental Horticulture* 18: 5–8. <Go to ISI>://BIOABS:BACD200100186647.

Palik, Brian J., Brooke K. Haworth, Andrew J. David, and Randall K. Kolka. 2015. “Survival and Growth of Northern White-Cedar and Balsam Fir Seedlings in Riparian Management Zones in Northern Minnesota, USA.” *Forest Ecology and Management* 337. Elsevier B.V.: 20–27. doi:10.1016/j.foreco.2014.10.033.

Ruttan, Ally, and Christopher J. Lortie. 2015. “A Systematic Review of the Attractant-Decoy and Repellent-Plant Hypotheses: Do Plants with Heterospecific Neighbours Escape Herbivory?” *Journal of Plant Ecology* 8 (4): 337–46. doi:10.1093/jpe/rtu030.

Slifer, Geoffrey, John Grande, and Larry Katz. 2010. “High-Tensile Woven Wire Fences for Reducing Wildlife Damage.”

Smit, Christian, Charlotte Vandenberghe, Jan Den Ouden, and Heinz Müller-Schärer. 2007. “Nurse Plants, Tree Saplings and Grazing Pressure: Changes in Facilitation along a Biotic Environmental Gradient.” *Oecologia* 152 (2): 265–73. doi:10.1007/s00442-006-0650-6.

Stange, Erik E, and Kathleen L Shea. 1998. “Effects of Deer Browsing , Fabric Mats , and Tree Shelters on Quercus Rubra Seedlings.” *Restoration Ecology* 6 (1): 29–34. doi:10.1046/j.1526-100x.1998.00614.x.

Sweeney, Bernard W., Stephen J. Czapka, and Tina Yerkes. 2002. “Riparian Forest Restoration: Increasing Success by Reducing Plant Competition and Herbivory.” *Restoration Ecology* 10 (2): 392–400. doi:10.1046/j.1526-100X.2002.02036.x.

Trent, Andy, Dale Nolte, and Kimberly Wagner. 2001. “Comparison of Commercial Deer Repellents.” *USDA National Wildlife Reserch Center* 572.

Ward, Js, and Sc Williams. 2010. “Effectiveness of Deer Repellents in Connecticut.” *Human–Widlife Interactions* 4 (1): 56–66. http://www.wildlifeconflicts.org/journal/spring2010/ward_williams_sp10.pdf.

White, Mark A. 2012. “Long-Term Effects of Deer Browsing: Composition, Structure and Productivity in a Northeastern Minnesota Old-Growth Forest.” *Forest Ecology and Management* 269: 222–28. doi:10.1016/j.foreco.2011.12.043.

Annotated Bibliography

Bee, Jennie N., Andrew J. Tanentzap, William G. Lee, Roger B. Lavers, Alan F. Mark, James A. Mills, and David A. Coomes. 2009. “The Benefits of Being in a Bad Neighbourhood: Plant Community Composition Influences Red Deer Foraging Decisions.” Oikos 118 (1): 18–24. doi:10.1111/j.1600-0706.2008.16756.x.

A study of deer herbivory in New Zealand showed that the quality of forage available within a patch of landscape influenced the feeding patterns of deer, with deer preferring patches where high quality forage was available. This study shows that deer make decisions about foraging on both a local and landscape scale, and that species more palatable to deer may be sheltered if planted within a path of less palatable species, while planting many palatable species together may increase the attractiveness of the patch to herbivores.

Callaway, Ragan M., David Kikodze, Marina Chiboshvili, and Liana Khetsuriani. 2005. “Unpalatable Plants Protect Neighbors From Grazing and Increase Plant Community Diversity” 86 (7): 1856–62.

Less palatable species can deter herbivores from feeding in an area, which can facilitate the growth of other species more sensitive to herbivores. These species can dominate the plant community, and if herbivory pressure is low or absent, can reduce the community diversity But in areas of high herbivory pressure, can contribute to an increase in plant diversity relative to areas where they are absent.

Dubois, M. R., A. H. Chappelka, E. Robbins, G. Somers, and K. Baker. 2000. “Tree Shelters and Weed Control: Effects on Protection, Survival and Growth of Cherrybark Oak Seedlings Planted on a Cutover Site.” New Forests 20 (2): 105–18. doi:10.1023/A:1006704016209.

Tree shelters can be initially expensive, increasing the cost of tree planting by more than $4 a tree, but provide highly effective protection from deer browse and significantly increased survival rates for species protected. Weed control enhanced growth when combined with tree shelter treatments, but also increased the cost of management. Weed control treatments alone were not effective in increasing tree seedling survival, and actually increased seedling mortality.

Horsley, S. B., S. L. Stout, and D. S. De Calesta. 2003. “White-Tailed Deer Impact on the Vegetation Dynamics of a Northern Hardwood Forest.” Ecological Applications 13 (1): 98–118.

This study used experimental densities of deer to compare the long-term effects of deer density on the vegetation structure of forests within deer enclosures. The authors found a significant increase in the growth of browse sensitive species at lower deer densities, while species less sensitive to deer browse flourished under higher densities of deer.

Laliberté, Etienne, André Bouchard, and Alain Cogliastro. 2008. “Optimizing Hardwood Reforestation in Old Fields: The Effects of Treeshelters and Environmental Factors on Tree Seedling Growth and Physiology.” Restoration Ecology 16 (2): 270–80. doi:10.1111/j.1526-100X.2007.00270.x.

In addition to the protection they provide against herbivory, tube tree shelters can improve the growth rate of some trees grown under high light conditions, potentially enhancing restoration outcomes in areas under moderate or low deer browse intensity. This study also shows that tree tubes can reduce growth by limiting light to the seedling if there is heavy cover from other vegetation that limits light availability.

Lemieux, Nicole C, Brian K Maynard, and William A Johnson. 2000. “Evaluation of Commercial Deer Repellents on Ornamentals in Nurseries.” Journal of Environmental Horticulture 18: 5–8. <Go to ISI>://BIOABS:BACD200100186647.

Deer repellants do not eliminate the threat of deer herbivory, but can significantly reduce the amount of browsing experienced by ornamental plants. The efficacy of deer repellant depends on the relative intensity of herbivory pressure, and in areas with high deer activity; certain herbicides may not be effective in reducing browse damage.

Palik, Brian J., Brooke K. Haworth, Andrew J. David, and Randall K. Kolka. 2015. “Survival and Growth of Northern White-Cedar and Balsam Fir Seedlings in Riparian Management Zones in Northern Minnesota, USA.” Forest Ecology and Management 337. Elsevier B.V.: 20–27. doi:10.1016/j.foreco.2014.10.033.

The authors compared the growth of planted white cedar, a browse-sensitive species, to the growth of balsam fir, a less sensitive species, in areas protected and unprotected by deer fencing. The authors found higher rates of seedling survival for white cedar in fenced areas, but no significant difference in balsam fir survival rates, suggesting that the effectiveness of deer exclosures may depend on the species.

Ruttan, Ally, and Christopher J. Lortie. 2015. “A Systematic Review of the Attractant-Decoy and Repellent-Plant Hypotheses: Do Plants with Heterospecific Neighbours Escape Herbivory?” Journal of Plant Ecology 8 (4): 337–46. doi:10.1093/jpe/rtu030.

This article is a meta-analysis of literature showing support for the idea that plants unpalatable to herbivores also provide that protection to adjacent species that are more palatable. A systematic review of the literature supports the “repellent-plant” hypothesis in the context of mammalian herbivory in broadleaf forests, and supports the use of less palatable species along with more palatable species to make areas less attractive as food sources for deer.

Smit, Christian, Charlotte Vandenberghe, Jan Den Ouden, and Heinz Müller-Schärer. 2007. "Nurse Plants, Tree Saplings and Grazing Pressure: Changes in Facilitation along a Biotic Environmental Graunpdient." Oecologia 152 (2): 265–73. doi:10.1007/s00442-006-0650-6.

This article shows that the protection provided by unpalatable plants depends on the intensity of other stressors, particularly the intensity of herbivory. Under high pressure from herbivory, unpalatable plants may not provide any benefit to the more palatable species they are associated with, especially as herbivores begin to consume less-palatable species more frequently.

Slifer, Geoffrey, John Grande, and Larry Katz. 2010. "High-Tensile Woven Wire Fences for Reducing Wildlife Damage."

This publication by Rutgers University details the logistical considerations of installing deer fencing, including the approximate cost per foot, as well as installation methods. In particular, it addresses concerns about self-installation versus using a contractor, and the tradeoffs of different methods for setup, such as auguring fence posts versus driving them in.

Stange, Erik E, and Kathleen L Shea. 1998. "Effects of Deer Browsing, Fabric Mats, and Tree Shelters on Quercus Rubra Seedlings." Restoration Ecology 6 (1): 29–34. doi:10.1046/j.1526-100x.1998.00614.x.

This study shows the effectiveness of tree shelters and weed control in reducing the mortality due to herbivory. In particular, it shows that weed suppression on its own actually increased tree mortality, so combinations of treatments may be significantly more effective than individual treatments, and the effectiveness management strategies implemented will depend on the ecological context.

Sweeney, Bernard W., Stephen J. Czapka, and Tina Yerkes. 2002. "Riparian Forest Restoration: Increasing Success by Reducing Plant Competition and Herbivory." Restoration Ecology 10 (2): 392–400. doi:10.1046/j.1526-100X.2002.02036.x.

This study documented the response of different species of native tree seedlings to tree shelter treatment. The authors show that even under very heavy deer herbivory, survival improves significantly with the use of tree shelters. The study also shows that species vary in sensitivity to deer herbivory, so if resources are limited, some species may benefit more from tree shelters. Finally, it demonstrates efficacy of tree shelter use in Maryland, providing evidence to support the use of tree shelters in reforestation in a relatively local context.

Trent, Andy, Dale Nolte, and Kimberly Wagner. 2001. "Comparison of Commercial Deer Repellents." USDA National Wildlife Research Center 572.

This study of deer repellents looked at the efficacy of different active ingredients used in commercial deer repellents. In particular, it found the repellents that triggered a fear response and contained putrefied animal proteins, such as egg and blood meal, provided the most effective control of herbivory. The study also mentions factors that may influence the effectiveness of deer repellents, including weather, deer population density, and the availability of alternative food sources.

Ward, J.S., and S.C. Williams. 2010. "Effectiveness of Deer Repellents in Connecticut." Human–Wildlife Interactions 4 (1): 56–66.

This study compared commercially available deer repellents of different prices with protective fencing in deer browse reduction. It found that more expensive repellents applied more frequently provided the best protection, but less expensive options could still provide some level of protection at a fraction of the cost or application frequency.

White, Mark A. 2012. "Long-Term Effects of Deer Browsing: Composition, Structure and Productivity in a Northeastern Minnesota Old-Growth Forest." Forest Ecology and Management 269: 222–28. doi:10.1016/j.foreco.2011.12.043.

This study investigated the outcome of a 17-year deer exclusion study on vegetation dynamics. The authors set up deer exclosures and unfenced comparison plots, and tracked the number and species of living tree stems greater than 2.5 cm in each plot. The authors found significant differences in the vegetation of fenced and unfenced plots, with fenced plots having greater numbers of browse-sensitive trees, and unfenced plots consisting of a larger number of species less sensitive to deer browse, particularly white spruce and balsam fir. This study shows that deer fundamentally alter the biodiversity of forests, and long-term deer exclosures can modify the vegetation structure of forests by promoting the growth of browse-sensitive species in areas heavily impacted by deer.