The Effects of Girdling on Tree Seedlings in the Western Fields and Forest of St. Olaf Campus

Steven J. Parker

Biology 371

Professor Kathy Shea

December 14, 1994

ABSTRACT

Tree seedlings in Field One, Field Two, and in Manitou Woods of St. Olaf College, Northfield, MN, were examined for girdling. Meadow voles (*Microtus pennsylvanicus*) can have a profound effect on the rate of tree seedling survival. The extensive vegetative cover spanning the majority of the two fields provides a favorable warm, protective habitat for vole populations. The three null hypotheses tested were: 1) The frequency of all the tree species girdled is the same, 2) girdled and non-girdled trees have equal survival rates, and 3) the frequency of protected (tubex) and unprotected tree species girdled in the fields and in Manitou Woods is the same.

The results showed that some tree species were favored over others. White ash and red maple were most favored by the voles. The highest proportion of girdling occurred in the field with both the highest density of vegetation and the lowest elevation. A significant amount of girdled tree seedlings had sucker shoots and buds. This correlated positively with extremely high survival rates, despite extensive girdling in areas. The fact there were very few deaths indicated that girdled and non-girdled trees had nearly equal survival rates.

There was minimal evidence of girdling in Manitou Woods, in comparison to a surprisingly high amount on the tubex trees. The highest proportion of girdling occurred on the unprotected seedlings in Field One. Therefore, the frequency of girdling of the tree species in the three different microclimates varied. As long as high survival rates of all the seedling species continues, there will be no delays or patchiness in old-field succession.

INTRODUCTION

According to Ostfeld (1993), seedling predation can (1) delay old-field succession by reducing the number of tree invaders, (2) create patchiness by concentrating surviving seedlings in certain microsites, and (3) alter relative abundances of invading species. A common form of seedling predation is girdling.

Girdling is a phenomena in nature defined as the gnawing of the outer bark of a tree by a herbivore. The worst episodes of girdling may occur during the harshest span of winter. The winter of 1993-94 was especially long and harsh. As a result, extensive girdling was done to the tree seedlings in the western fields of St. Olaf campus and also to the tree seedlings at the Hennepin County Nursery.

The extent of girdling determines whether it will survive or die. Girdling usually has no immediate effects on transpiration, since water movement occurs in the xylem, which is interior to the bark (Taiz and Zeiger, 1991). Girdling would more likely damage the phloem first, which is concentrated in the outer bark of the tree (Taiz and Zeiger, 1991).

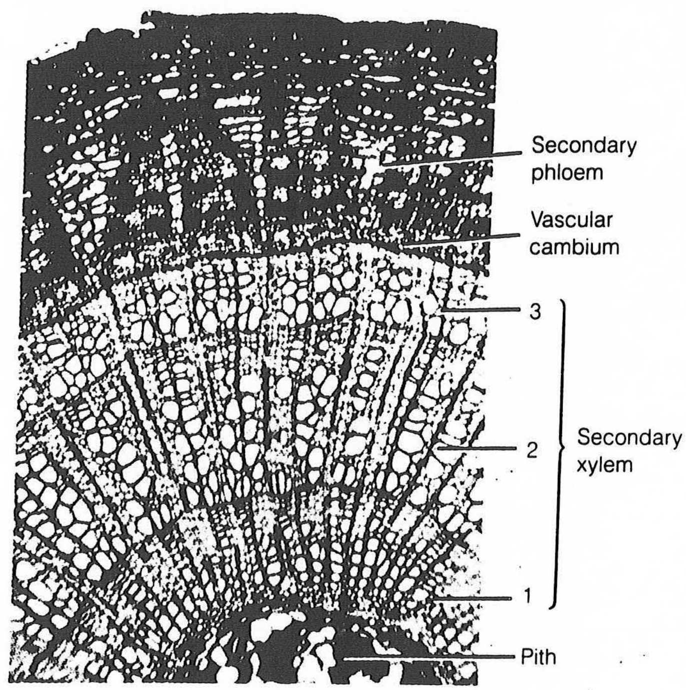

Figure 1. Transverse section of a linden (*Tilia americana*) tree (50x), showing the morphological arrangement of phloem and xylem tissues. Only the most recent layer of secondary phloem is functional (Taiz and Zeiger, 1991).

The phloem tissue is where translocation takes place. Here minerals, nutrients, and ions are transported down the tree from the source (leaves and other sites of photosynthesis) to the sink (roots and other sites of metabolism and/or storage). If the vascular tissue becomes completely severed, nutrient flow to the bottom of the tree and water flow to the upper portion of the tree would be cut off and the tree will die. If damage from girdling is partial, the tree seedling might be able to regenerate by sprouting up other stem(s) from the base. The appearance of buds on a tree is another good indication that the tree seedling is still alive.

The fact that the girdling on the St. Olaf tree seedlings was done near the base indicates that the culprit was a small rodent. Meadow voles (Figure 2), *Microtus pennsylvanicus*, which inhabit the region, can have a profound impact on seedling survival.

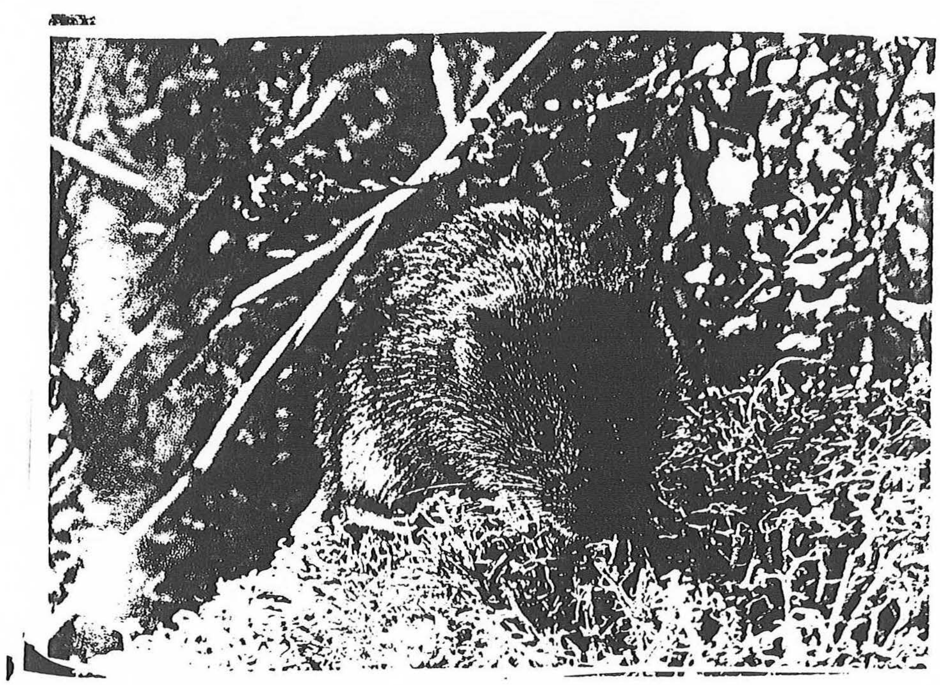

Figure 2. Photo of a meadow vole, *Microtus pennsylvanicus* (Hayes, 1984).

Meadow voles are prolific in nature and are active year round. The young *Microtus* can breed within five weeks of age and can have litters up to nine (Hayes, 1984). They prefer grassy orchards and forage every couple of hours exclusively above ground on fresh leaves and stems of a variety of plants to help fuel their high metabolism (Richmond and Tobin, 1987).

The first goal of this study was to find how many and what kind of tree seedlings were girdled in the fields (both in and out of light tubes) and in Manitou forest of St. Olaf College, Northfield, MN. The second goal was to determine whether the girdled tree seedlings survived or not. Survival was indicated by the presence of: leaves (if they hadn't dropped yet), sucker shoots from the stem, and/or buds on the main stem. The null hypotheses tested were: 1) The frequency of all the tree species girdled is the same, 2) girdled and non-girdled trees have equal survival rates, and 3) the frequency of protected (tubex) and unprotected tree species girdled in the fields and in Manitou Woods is the same.

Methods

The experiment took place primarily in Field One behind Manitou Woods. The field is permanently divided into twelve plots. The data was collected from the odd-numbered plots because the tree seedlings in those plots were labeled. In addition, two plots (15 and 17) from the adjacent Field Two were targeted for data collecting. These two plots were the ones that contained the tubex trees. This allowed comparison for the frequency of girdling that occurred on the protected tree seedlings inside the light tubes with the unprotected seedlings from Field One.

All of the tree seedlings in the fields were identified with metal tags that were previously nailed into the ground near the base of the stem. The tags indicated the species, its number, and the year it was planted. Each seedling was recorded onto a spreadsheet when it was originally planted. The present status of each seedling was logged onto the column "comments" of the spreadsheet. This prevented possible errors from duplicated sightings.

Transects were made into the woods from the ends of plots two, three, and six in field one. The three transects were each thirty-five meters in length. The extra five meters accounted for the approximate width of the cross-country trail that winds its way through the edge of the forest. Tree seedlings less than two meters in height that were within one meter of the transect line were included in the study. The fifty meter field measuring tape was used. The seedlings, whose leaves had fallen off, were keyed out with the aid of Deciduous Trees of Minnesota: a Winter Key.

Results

Although Table 1 shows that quite a few trees were girdled, there was little evidence of death as a result. Eighty-six seedlings were girdled and only eight were dead. There was no difference in the top six species between the number of alive and dead individuals (Table 2).

The contingency table (Table 4) shows that the frequency between girdling and no girdling differed for the six most abundant species. Forty-four percent of the white ash trees (*Fraxinus americana*) were girdled in Fields One and Two (Table 3). A high proportion of white oaks (*Quercus alba*) and red maples (*Acer rubrum*) were also girdled. The proportion of the six most popular species girdled in the fields are displayed in Figure 3. All except three species had a higher proportion of girdling in denser vegetation. Table 5 and Figure 4 further show that the frequency of girdling was not equal for different species in sparse versus dense vegetation. The frequency of girdling was different between high and low elevations for the top six species (Table 6 and Figure 5), with the highest proportion of girdling occurring in the lower elevation (plots 7-11) of Field One (Table 3).

Table 7 shows that there was a higher proportion of alive, girdled trees with sucker shoots than with alive trees in general with sucker shoots. Sucker shoots were more common in seedlings that were girdled than in seedlings that were not girdled. Table 8 also indicates that there was a linear relationship between the alive and girdled trees with and without sucker shoots. The proportions of alive and girdled trees with sucker shoots in the fields are displayed in Figure 6.

Table 9 reveals that the highest amount of girdling occurred in Field One and Two (tubex) for the four most common seedling species. Hardly any girdling occurred in Manitou Woods. White ash was the only species in that grouping that was girdled in the forest. Since the p-values were less than .05 in Tables 11 and 12, there was a difference in frequency of girdling between the protected and

Table 1. The numbers of alive, dead, girdled, and not girdled for fifteen species of trees in the odd-numbered plots (1-17) of fields one and two, St. Olaf College.

Species	Total no.	No. Alive	No. Dead	No. Girdled	No. not girdled
white ash	79	79	0	35	44
black walnut	75	72	3	7	68
bur oak	72	71	1	8	64
white oak	68	65	3	17	51
sugar maple	24	24	0	5	19
ironwood	20	20	0	4	16
northern red oak	15	15	0	1	14
red maple	15	15	0	5	10
basswood	7	7	0	0	7
honeylocust	5	4	1	1	4
wild plum	2	2	0	1	4
honeysuckle	2	2	0	0	2
Russian olive	2	2	0	1	1
green ash	1	1	0	1	0
cherry	2	1	0	0	1

Table 2. Contingency table analysis of the frequency of alive and dead for tree species in Fields One and Two.

Summary Statistics

DF:	5	
Total Chi-Square:	6	p = .3082
G Statistic:	•	
Contingency Coefficient:	1E-1	
Cramer's V:	1E-1	

Table 3. The proportions of fifteen different tree species girdled in varying densities of vegetation and of varying elevation in fields one and two.

Species	% Girdled in all fields	% Girdled in sparse vegetation	% Girdled in dense vegetation	% Girdled in high elevation plot #1-5	% Girdled in low elevation plot #7-11
white ash	.443	.167	.466	.292	.550
black walnut	.093	.125	.085	0	.079
bur oak	.111	0	.163	.075	.267
white oak	.333	.100	.236	.283	.182
sugar maple	.208	.200	.214	.214	.286
ironwood	.200	0	.286	.111	.273
northern red oak	.071	0	.083	0	.250
red maple	.333	.500	.444	--	--
basswood	0	0	0	0	0
honeylocust	.200	0	100	0	.250
wild plum	.200	0	.200	0	.333
honeysuckle	0	0	0	0	0
Russian olive	.500	.500	0	100	0
green ash	100	0	100	0	100
cherry	0	0	0	0	0

Table 4. Contingency table analysis of girdled and non-girdled trees in Fields One and Two.

Summary Statistics

DF:	5	
Total Chi-Square:	35	p = .0001
G Statistic:	34	
Contingency Coefficient:	3E-1	
Cramer's V:	3E-1	

Figure 3. Proportion of tree species girdled in Fields One and Two.

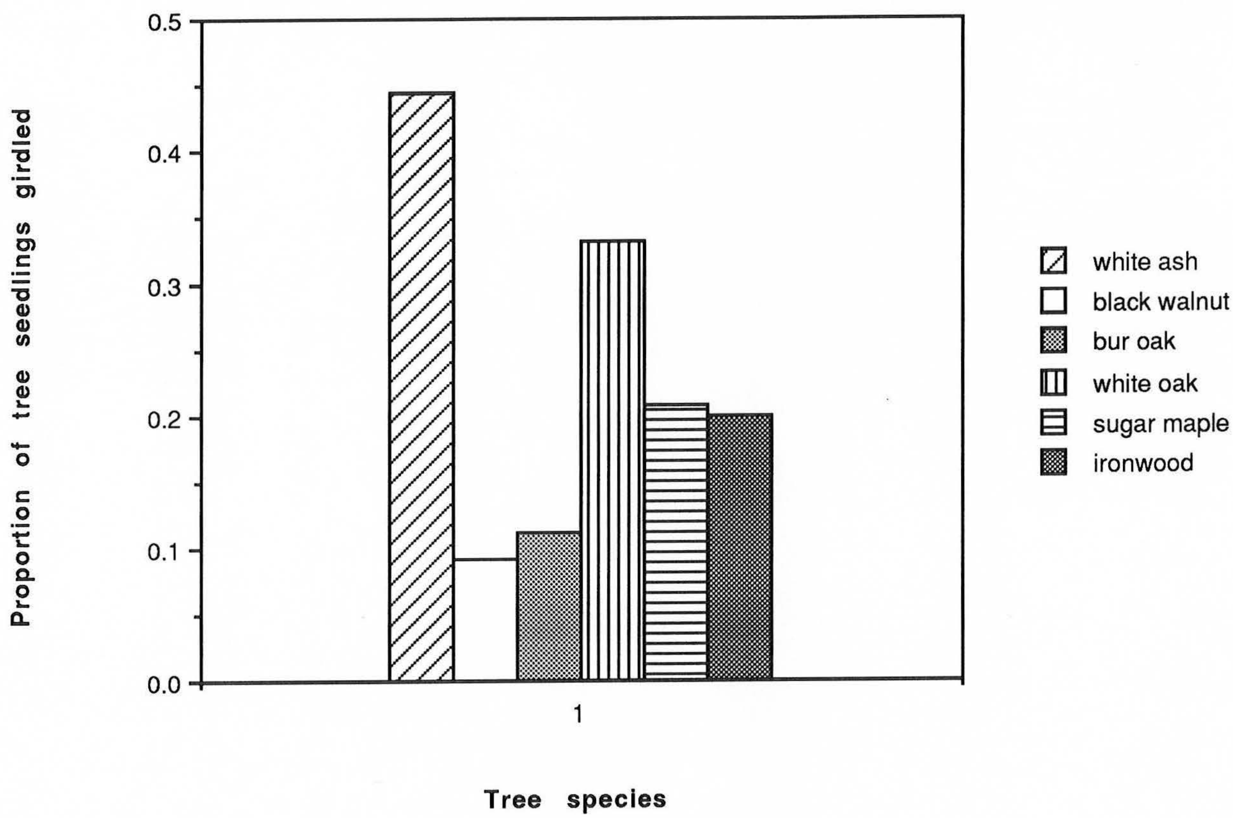

Table 5. Contingency table analysis of girdling on tree species in sparse versus dense vegetation, Fields One and Two.

Summary Statistics

DF:	5	
Total Chi-Square:	13	p = .0237
G Statistic:	•	
Contingency Coefficient:	4E-1	
Cramer's V:	4E-1	

Table 6. Contingency table analysis of girdling on tree species in high and low elevations of Fields One and Two.

Summary Statistics

DF:	5	
Total Chi-Square:	19	p = .0018
G Statistic:	•	
Contingency Coefficient:	5E-1	
Cramer's V:	1	

Figure 4. Proportion of trees girdled as a function of sparse and dense vegetation.

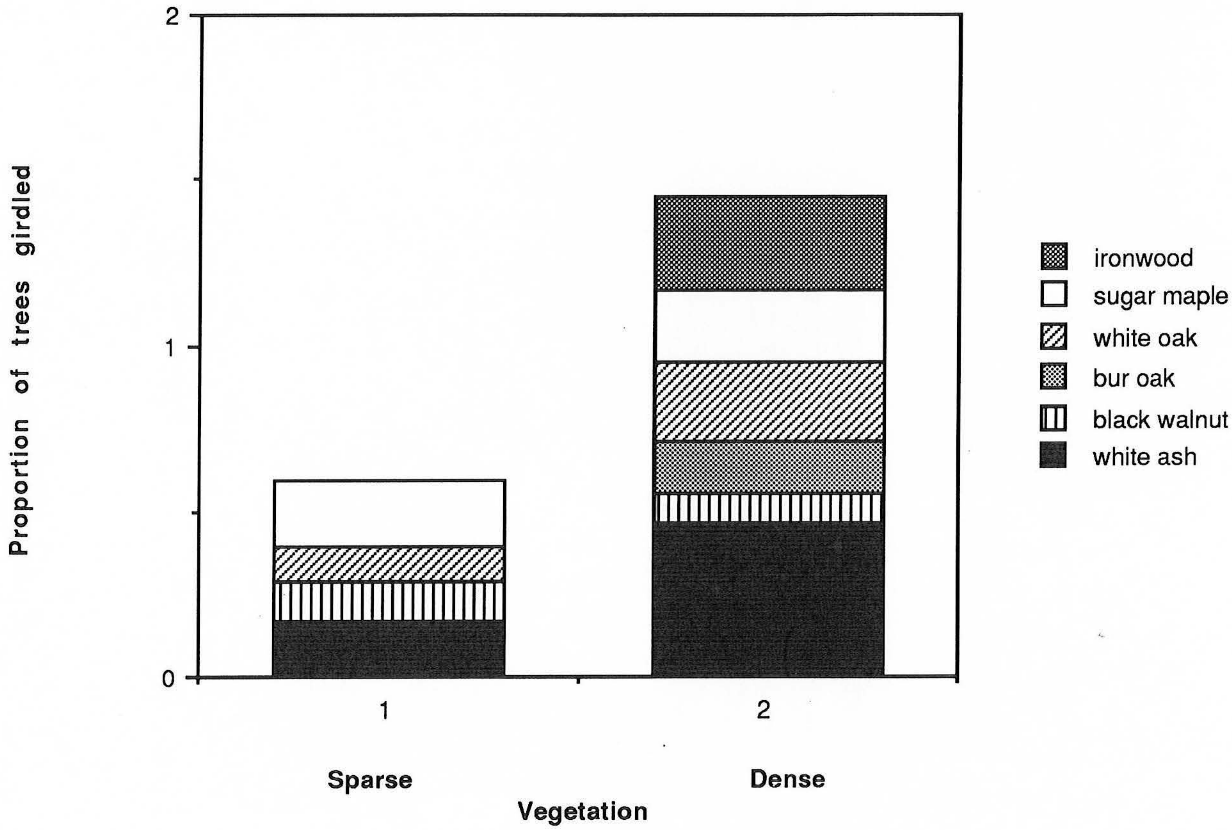

Figure 5. Proportion of tree species girdled as a function of high and low elevation.

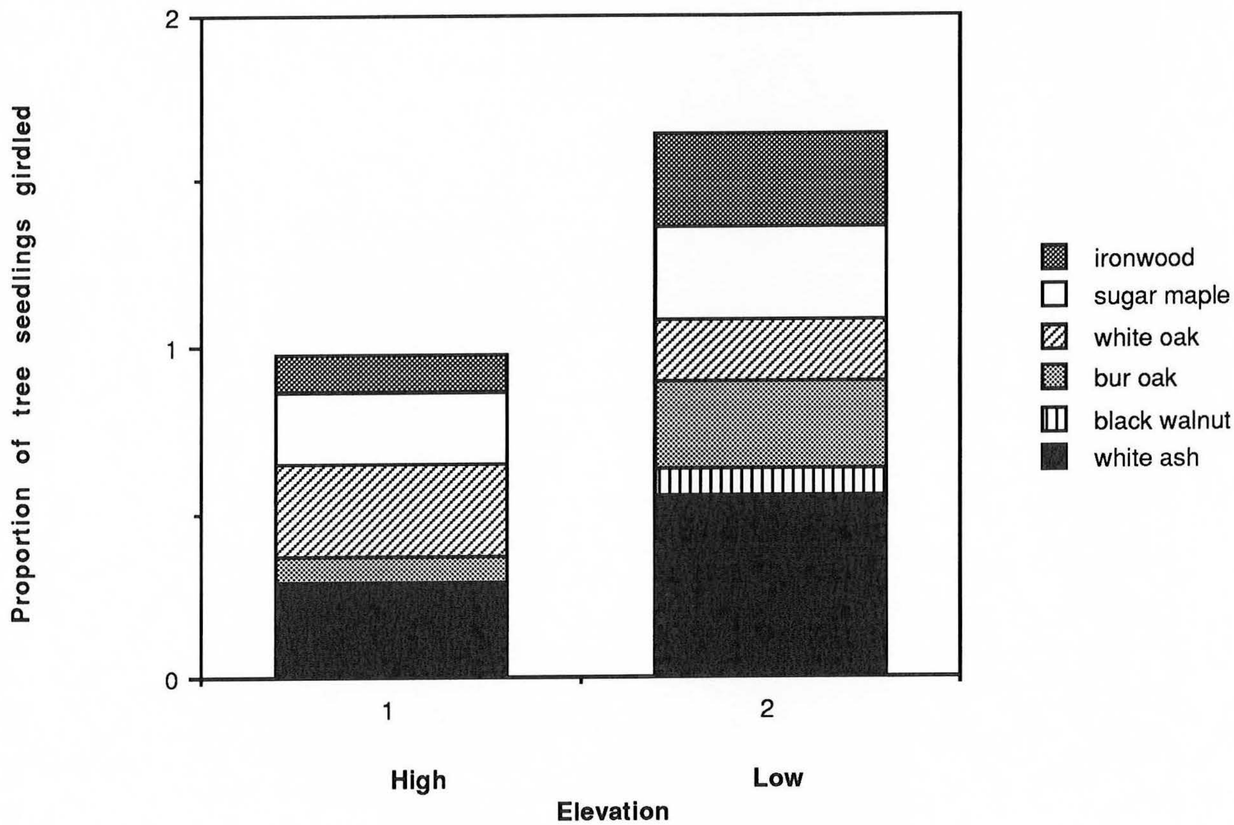

Table 7. The proportion of girdled and non-girdled trees that have sucker shoots in fields one and two.

Species	Proportion of alive trees with sucker shoots	No. of alive and girdled trees with sucker shoots	No. of alive and girdled trees without sucker shoots	Proportion of alive and girdled trees with sucker shoots
white ash	.306	18	17	.514
black walnut	.040	1	5	.429
bur oak	.028	2	6	.250
white oak	.123	8	9	.471
sugar maple	.042	2	3	.667
ironwood	.250	1	3	.250
northern red oak	0	0	1	0
red maple	0	0	5	0
basswood	0	0	0	0
honeylocust	.250	1	0	100
wild plum	0	0	1	0
honeysuckle	0	0	0	0
Russian olive	0	0	1	0
green ash	100	1	0	100
cherry	0	0	0	0

Table 8. Contingency table analysis of alive and girdled tree species with and without sucker shoots, Fields One and Two.

Summary Statistics

DF:	5	
Total Chi-Square:	6	p = .307
G Statistic:	6	
Contingency Coefficient:	3E-1	
Cramer's V:	3E-1	

Figure 6. Proportion of alive and girdled trees with sucker shoots in Fields One and Two.

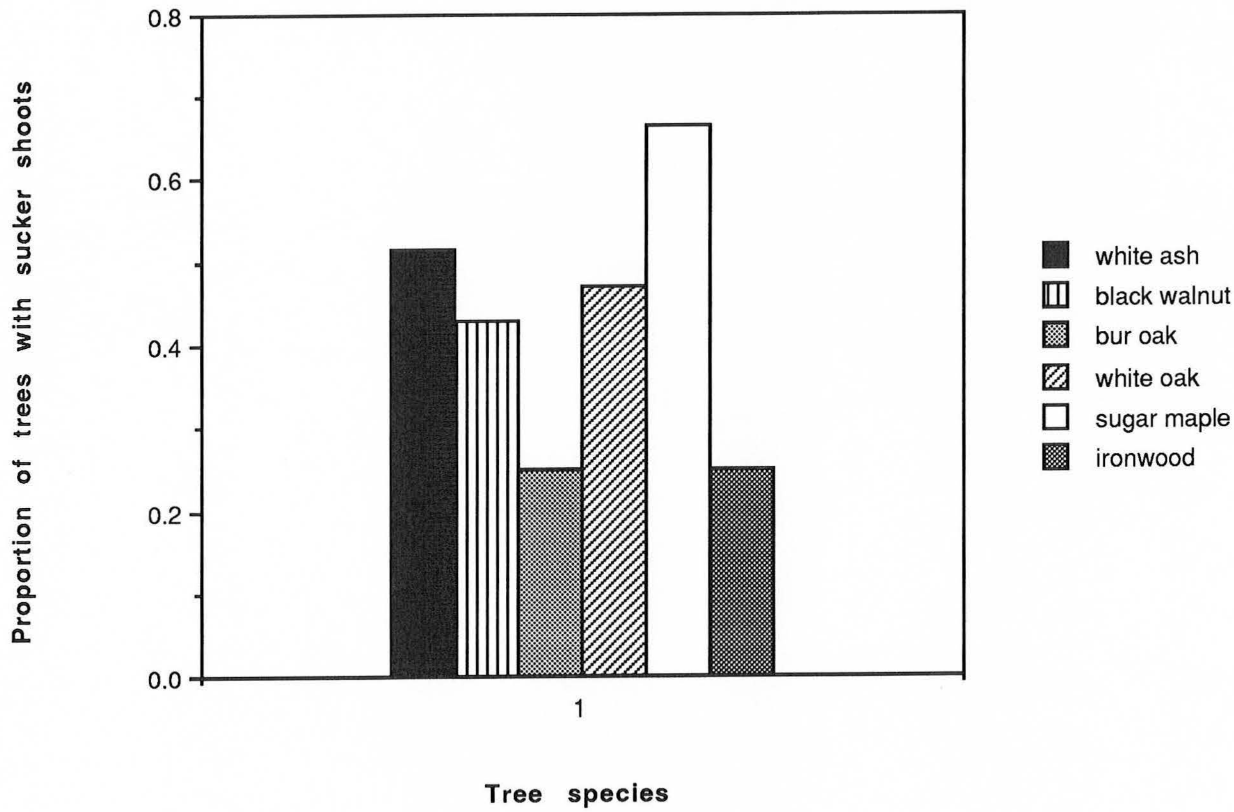

Table 9. Comparisons of the frequency girdling of the four most common tree species in field one, field two (tubex), and in Manitou Woods.

Species	Location	Girdling	No girdling
white ash	forest	1	3
	field	29	35
	tubex	6	9
black walnut	forest	0	0
	field	3	40
	tubex	4	28
bur oak	forest	0	9
	field	8	61
	tubex	0	3
white oak	forest	0	23
	field	17	51
	tubex	0	0

Table 10. Contingency table analysis of the frequency of girdled and non-girdled white ash species in the forest and fields.

Observed Frequency Table

	Column 1	Column 2	Totals:
Forest	1	3	4
Field	29	35	64
Tubex	6	9	15
Totals:	36	47	83

1	p = .6986

Table 11. Contingency table analysis of the frequency of girdled and non-girdled black walnut species in the forest and fields.

Observed Frequency Table

	Column 1	Column 2	Totals:
Forest	0	0	0
Field	3	39	42
Tubex	4	25	29
Totals:	7	64	71

p = .0001

Table 12. Contingency table analysis of the frequency of girdled and non-girdled white oak species in the forest and fields.

Observed Frequency Table

	Column 1	Column 2	Totals:
Forest	0	23	23
Field	17	51	68
Tubex	0	0	0
Totals:	17	74	91

p = .0001

unprotected white ash and black walnut (*Juglans nigra*) seedlings in the fields and in the forest.

Discussion

Frequency of girdling

Some species were girdled more frequently than others. Table 3 shows white ash, red maple, and white oak had the highest proportion girdled. White ash and red maple were also found by Ostfeld (1993) to be the two most sensitive tree species to girdling. The results from the contingency table (Table 4) indicated that there was no linear relationship between the frequency of trees girdled and trees not girdled for the six most abundant species in Fields One and Two. Therefore, the null hypothesis was rejected in which the frequency of all the tree species girdled is the same.

In contrast, black walnut, bur oak (*Quercus macrocarpa*), and northern red oak (*Quercus borealis*) had much lower frequencies of girdling. The two oak species were probably avoided because oaks in general produce high amounts of tannins (Howard and Lamb, 1985), which are defensive secondary compounds, often avoided by herbivores.

Survival rates of girdled and non-girdled seedlings

A significant amount of girdled trees had sucker shoots and buds. This correlated positively with extremely high survival rates, despite extensive girdling in areas. Table 1 revealed that only eight out of three hundred eighty-nine tree seedlings were found to be dead. Further analysis disclosed a high p-value (Table 2), which led to the acceptance of the null hypothesis that there are equal survival rates of girdled and non-girdled tree species.

Girdled trees had a higher proportion of sucker shoots than non-girdled trees (Table 7). Another study (Ostfeld, 1993) has shown that many damaged seedlings severed near the ground level were left in place, indicating they were rejected as food. This corresponds with Ostfeld's (1993) hypothesis that voles attack seedlings largely in the process of tasting plants.

In general, trees are poorer in nutritional quality than grasses and other lower-lying vegetation. The portion of the vascular tissue most likely to be girdled first is the phloem. The inorganic solutes transported in the phloem include potassium, magnesium, phosphate, and chloride (Taiz and Zeiger, 1991). A study by Mickelson (1991) revealed an avoidance of high-potassium diets by captive meadow voles. The possible presence of potassium in the phloem of trees seedlings in Fields One and Two may have deterred voles from girdling more severely.

Frequency of girdling on varying species in different microclimates

The null hypothesis that the frequency of girdling in the three microclimates is the same was rejected. As indicated in Table 9, there was little evidence of girdling on the tree seedlings in Manitou Woods. The forest floor wasn't as favorable an environment as the tallgrass in Fields One and Two. The forest floor was relatively vegetation-free due to the lack of sunlight penetration underneath the canopy of trees. High concentrations of voles weren't predicted to be in the forest because the main diet of voles consists primarily of grasses, sedges, and forbes (Ostfeld, 1985), which are located in the fields. Vole populations were probably centered in areas with the highest concentrations of food sources (fields).

The frequency of girdling was much higher in the fields. The higher frequency of girdling in this microclimate could probably be explained by the presence of the highest density of the vole population. Voles typically thrive under the network of tallgrass, which provides a warmer, more suitable microclimate during the cold season. Tallgrass also provides more protection from predators. Repeated studies have shown girdling to strongly correlate with peak vole densities. An overabundance of voles may lead to partitioning of food sources, where new foods (trees) may be sampled as a means of establishing a new niche.

The highest frequency of girdling occurred on the unprotected seedlings of Field One (Table 9). The protected tree seedlings (in light tubes) in Field Two also had fairly high girdling rates. It was evident light tubes weren't one hundred percent effective. Many of the light tubes were resting on the ground, rather than penetrating into it. The light tubes seemed to be sturdy enough to protect the seedlings from browsers, but not voles, whose bodies are only a few centimeters in width and length.

Effects of girdling in varying elevations and in different densities of vegetation in Fields One and Two

The proportion of girdling on tree seedlings was significantly higher in parts of the field with lower elevation and denser vegetation (Table 3). The contingency analysis (Table 5) showed a low p-value, which rejected the null hypothesis that the frequency of girdling is the same for different species in environments that are sparse and dense in vegetation. The absence of any linear relationship between the frequency of girdling in high and low elevations was supported by the results from the contingency analysis (Table 6).

Gill and Marks (1991) also found seedlings planted in small clearings to be much less likely to be attacked and killed by voles. The higher elevation in Field One was complemented with little ground cover. Without vegetation, the elevated part of the field didn't provide an attractive habitat for voles to live. Without the warmth, protection, and primary food source that vegetation provides, vole populations weren't concentrated there, and as a result, there was less girdling.

Future control of vole populations

A recent peak in vole population may have been the cause of a higher frequency of girdling. A typical vole population fluctuates cyclically, with three to four years in between each peak (Hansson and Henttonen, 1988). If the extensive girdling was caused by a peak in population numbers, then there should be a three to four year span before the extent of girdling experienced last winter will be paralleled.

Keeping the prolific vole populations in check may reduce the frequency of girdling. Occasionally mowing the grassy areas around seedlings would eliminate the warm, protective microclimate voles thrive in (Richmond and Tobin, 1987). Trapping meadow voles might help, but its effectiveness would be questioned in the snow. Natural controls is another alternative. Having the DNR introduce a pair of Great Horned Owls into the vicinity might work wonders. A large percentage of an owls' diet is comprised of small rodents, in particular voles. Great Horned Owls are a species that prefer woody areas near open fields and could possibly adapt to the area well (Soper and Sparks, 1970). The owl pair would breed in the middle of winter and in the process would defend a five mile radius range of food (Spreyer, 1994).

Future implications from girdling

Although many seedlings survived girdling, the seedling could still die because of infections from pathogens that inflict the wounded area (Richmond and Tobin, 1987). If sap oozes from the girdled area, it could serve as a food source for ants, bees, and other anthropods.

Since voles didn't directly kill many tree species by girdling, there was no delay of old-field succession or patchiness created of invading tree species (Ostfeld, 1993). If old-field succession continues undisturbed, the fields will eventually turn into a young forest. The forest in Field One will consist of: White and bur oaks in the elevated, well-drained north end of the field, many white ashes occupying the opposite end of the field, and a lot of black walnuts distributed evenly throughout. The tubex trees in the north end of Field Two will grow up to be an edge of a forest, constituted of a mixture of black walnut, white ash, and red maple.

There will likely be less girdling in those fields in years to come due to the fact there will be a decline in overall nutritive quality of plants from early to late successional stages of the field (Bucyanayandi, 1990).

CONCLUSION

Meadow voles (*Microtus pennsylvanicus*) can have a profound effect on the rate of tree seedling survival. Currently, planted tree seedlings at St. Olaf College are located in fields that probably support high densities of voles, due to their extensive vegetative cover which provides a favorable warm, protective habitat. Other studies have indicated that cyclical density peaks in vole populations are main agents that result in extensive girdling.

The results from this study showed that some tree species were favored over others. White ash and red maple were heavily preferred by the voles. The highest proportion of girdling occurred in the field with both the highest density of vegetation and the lowest elevation.

A significant amount of girdled tree seedlings had sucker shoots and buds. This correlated positively with extremely high survival rates, despite extensive girdling in areas. The fact there were very few deaths indicated that girdled and non-girdled trees had nearly equal survival rates.

There was minimal evidence of girdling in Manitou Woods, in comparison to a surprisingly high amount on the tubex trees. The highest proportion of girdling occurred on the unprotected seedlings in Field One. Therefore, the frequency of girdling of the tree species in the three different microclimates varied.

Attempts can be made to control vole populations by reducing the vegetative cover, trapping them, or by introducing a pair of owls (biological control).

As long as high survival rates of all the seedling species continues, there will be no delays or patchiness in old-field succession. The composition of seedlings symbolizes the composition of future stands.

Literature Cited

Anderson and Strole. 1992. White-tailed deer browsing: species preferences and implications for central Illinois forests. Natural Areas Journal 12:139-144.

Buycyanayandi, J. 1990. Effects of food quality on feeding patterns of meadow voles (Microtus pennsylvanicus) along a community gradient. Journal of Mammalogy. 71(3):390-397.

Ewers, Frank and Jack Fisher. 1989. Wound healing in stems of lianas after twisting and girdling injuries. Botanical Gazette 150:251-265.

Gill, D. S. and P. L. Marks. 1991. Tree and shrub seedling colonization of old fields in central New York. Ecological Monographs 61:183-206.

Hansson, L. and H. Henttonen. 1988. Rodent dynamics as community processes. Trends in Ecology and Evolution 3:195-200.

Hays, H. 1984. The vole that soared. Natural History 93(5):7-12.

Lamb, S. and H. Miller. 1985. Oaks of North America. Naturegraph Publishers Inc., CA.

Mickelson, P. A. 1991. Avoidance of high-potassium diets by captive meadow voles. Journal of Mammalogy 72(1):177-182.

Ostfeld, R. S. 1993. Effects of meadow vole population density on tree seedling survival in old fields. Ecology 74(6): 792-802.

Ostfeld, R. S. 1985. Limiting resources and territoriality in microtine rodents. American Naturalist 126:1-15.

Richmond, M. E. and M. E. Tobin. 1987. Vole management in fruit orchards. Biological Report 5:1-18.

Soper, T. and J. Sparks. 1970. Owls: Their natural and unnatural history. Taplinger Publishing Co., New York.

Spreyer, M. 1994. Science Museum of Minnesota. Telephone interview.

Summer 1991 research summary: St. Olaf tree seedlings.

Taiz, L. and E. Zeiger. 1991. Plant physiology. The Benjamin/Cummings Publishing Co., Inc., Redwood City.