INTERFERENCE FACTORS RESPONSIBLE FOR RESISTANCE OF FORB-GRASS COVER TYPES TO TREE INVASION ON AN ELECTRIC UTILITY RIGHT-OF-WAY

by W.C. Bramble, W.R. Byrnes, R.J. Hutnik, and S.A. Liscinsky

Abstract. An investigation of factors responsible for resistance of forb-grass cover types to tree invasion was carried out from 1992 through 1994 on an electric transmission right-of-way (ROW) in central Pennsylvania. Unprotected seedspots and seedspots protected by wire cages were installed on the ROW to investigate the effect of the important interference factors of wildlife depredation, plant competition, and allelopathy. This field study was supplemented by pot culture tests of the effect of plant competition, seedbed condition, and allelopathy on tree seed germination and seedling growth in an environment where wildlife depredation, soil moisture, frost damage, and insect and disease attacks were controlled. The major factors that interfered with tree seed germination and seedling growth were wildlife depredation and plant competition by the dominant plant species of the forb-grass cover type, namely, poverty grass (*Danthonia spicata*), rough goldenrod (*Solidago rugosa*), and hayscented fern (*Dennstaedtia punctilobula*).
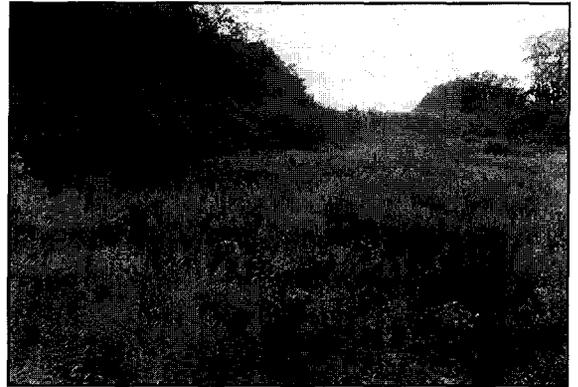

Figure 1. A forb-grass cover type dominated by poverty grass, rough goldenrod, and hayscented fern on the wire zone of a mowing, plus herbicide treatment unit in 1992, 5 years after treatment. Tree density was 50 trees per acre over 1 foot height. A witchhazel border is on the left.

Development of a plant cover type that is resistant to tree invasion has been an important contribution of our long-term ecological study on an electric utility transmission line right-of-way in central Pennsylvania (2). This tree-resistant plant cover type, designated as forb-grass based on its typical life forms, is dominated by rough goldenrod (*Solidago rugosa*), hayscented fern (*Dennstaedtia punctilobula*), and poverty grass (*Danthonia spicata*) that covered the ROW in dense patches (Figure 1). The cover type was produced by herbicide sprays in 1987, and, owing to reduced tree invasion, tree density in 1994 was less than 125 trees per acre over 1 foot height (6).

The objective of our current study was to answer the question "What makes the forb-grass cover type resistant to tree invasion?" Because the dominant plant species of the cover type have been reported to be allelopathic (8,9), it appeared possible that these were species that could be grown on the ROW to inhibit tree establishment and thus reduce the need for herbicides.

Although the important site factors that affect tree establishment from seeds were thoroughly described in early forestry texts (1), the concept of allelopathy as an important site factor was not fully recognized until later (11,12). It is of interest to note in connection with our current research that Putnam (11) referred to the adverse effect of a neighboring plant as "interference," and listed plant competition, selective feeding by herbivores, and allelopathy as potential causes.

An important investigation of allelopathy as a probable cause of failure of black cherry to reproduce in forest stands indicated that allelopathic interference by hayscented fern, rough goldenrod, and poverty grass appeared to play a strong role by inhibiting seed germination and growth of black cherry seedlings (8,9). A subsequent publication, however, reported that organic natural products present in foliage, leaching, root washings, or soil

from beneath hayscented fern did not interfere with black cherry seedling growth (10). Other factors, such as reduction in soil nitrate and light deficiency beneath fern, produced poor growth conditions that reduced survival of black cherry seedlings.

A thorough review of the literature on natural growth inhibitors prepared by the Brooklyn Botanical Garden contained a word of caution (7). "Very few of the allelopathic interactions between other vegetation and trees reported in the scientific literature stand up under the scrutiny of proof." However, in this review, it was also stated that "There is substantial evidence to indicate that tree invasion of a right-of-way can be prevented by herbaceous plants."

Our current study expands on an initial field study in 1992 of right-of-way site factors responsible for resistance of certain cover types to red maple invasion (5). Definite allelopathic inhibition of red maple seed germination and seedling growth by the ROW plants typical of the forb-grass cover type did not occur under field conditions. Instead, wildlife depredation and plant competition were found to be the important ROW interference factors.

Investigation of Wildlife Depredation

Method. The effect of protecting red maple (*Acer rubrum*) seeds and seedlings from wildlife depredation was investigated on the ROW in 1992. Seedspots were installed in pairs, one protected by a hardware cloth cage and the other left unprotected (Figures 2 and 3). The cages were 6 inches in height and 6 x 6 inches in area with 1-inch flanges, later enlarged to 6 inches. Four seedspot pairs were located in each of 4 replications of the 3 dominant ROW plants. Seventy-five red maple seeds were planted in each seedspot.

A similar method was used in 1994 to investigate the effect of protection from wildlife depredation on black cherry (*Prunus serotina*) seeds and seedlings. In this case, however, 3 replications of each of the 3 ROW plants were used and 5 seedspot pairs were installed in each replication. Ninety-five black cherry seeds were planted in each seedspot.

Results. Depredation on red maple seedspots. At 30 days after seeding red maple

Figure 2. A seedspot protected by a wire cage contained 19 red maple seedlings at 30 days after seeding. The seedbed was exposed mineral soil that laid under poverty grass.

Figure 3. An unprotected seedspot without seedlings at 30 days after seeding. The seedbed was exposed mineral soil that laid under poverty grass.

in litter of undisturbed vegetation (Figure 4), the seedling count on 12 protected seedspots averaged 5.2 per seedspot (Figure 5). In contrast, the seedling count on similar undisturbed seedbeds of 12 unprotected seedspots averaged 0.8 seedlings per seedspot. The difference between these 2 counts was significant at the 5% level when tested for significance between sample means (t-test).

Depredation on black cherry seedspots. Further evidence of wildlife depredation was obtained from a similar study in 1994 with protected and unprotected seedspots using black cherry seeds. Black cherry was selected because it ranks along with red maple as one of the 2 most common tree species invading the ROW. Loss of black

cherry on unprotected seedspots left 3.1 seedlings per seedspot at 30 days after seeding in contrast to 16.1 seedlings per seedspot on protected seedspots (Figure 5). The difference between the number of seedlings on protected seedspots compared with unprotected seedspots was significant at the 1% level (t-test).
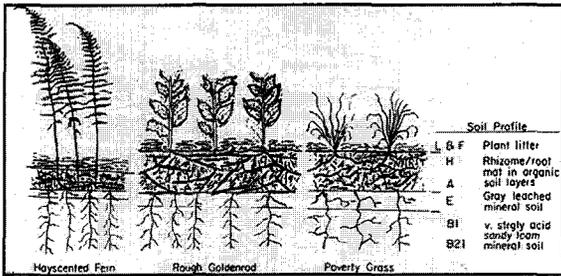

Figure 4. Soil profile under the 3 dominant species of the forb-grass ROW cover type. A thick litter (L) was underlain by a dense tangled mat composed of rhizomes and roots that occupied the black humus layer (H and A). The underlying mineral soil was an acid sandy loam (E and B).
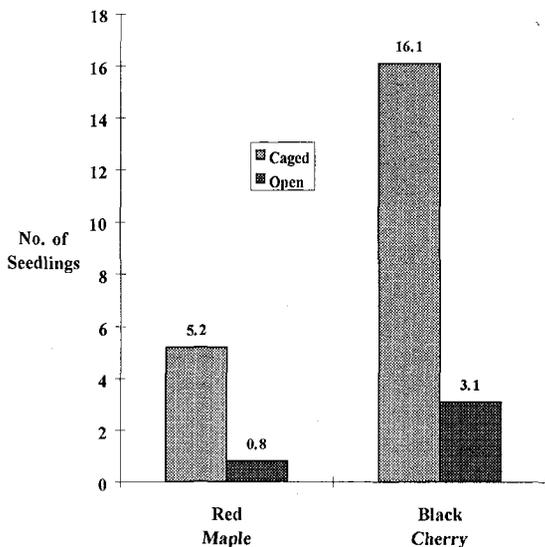

Figure 5. Average number of red maple and black cherry tree seedlings per seedspot on protected (caged) and unprotected (open) seedspots; 30 days after seeding, for 3 dorminant ROW species combined (poverty grass, rough goldenrod, and hayscented fern).

Wildlife species responsible for depredation. To help determine what wildlife species were responsible for the seed and seedling losses recorded, all seedspots were examined carefully and records taken at 3-day intervals for 30 days after seeding. These examinations were continued at 3–5 day intervals until August 1. A final examination was made on September 23.

A major cause of losses on unprotected seedspots was small mammals (mice, voles, and shrews). This was not unexpected, because a large and diverse population of these mammals was found in a previous study on the same ROW used in this study (4). Specifically, the forb-grass cover type was habitat for a small mammal population of 85 individuals per acre composed of 4 species (white-footed mouse, meadow vole, masked shrew, and meadow jumping mouse).

Small mammal activity was identified by typical digging and small holes found on unprotected seedspots along with small mammal droppings. The small mammals also dug at the edges of cages and made small holes as they tried to find an entrance. The 6-inch flange on the cages prevented successful entry, except for 1 case in which a mouse tunneled into the center of a caged seedspot with a 1-inch flange that had not yet been replaced by a 6-inch one.

Although a large bird population inhabited the ROW (3), no signs of bird activity on the seedspots was recorded. This may have been due to the location of the seedspots among a dense cover of forbs and grasses and to planting of tree seeds at a 3/4 inch depth rather than laid on the surface.

Other factors responsible for loss of seedlings. A few minor factors caused infrequent damage to red maple seedlings. The most unusual loss was caused by brown slugs (Arion faciatus) that invaded both caged and open seedspots where topsoil was used. In a special test, slugs put into a petri dish, along with 11 red maple seedlings, ate 7 of the 11 in 24 hours.

Only occasional damage to tree seedlings was caused by other factors such as insects, damping-off fungi, and frost heaving.

A Field Investigation on the Effect of Seedbed Condition and Plant Competition on Tree Seeds and Seedlings

Method. Red maple seedspots. To investigate the relative importance of plant competition and associated seedbed conditions, 75 red maple seeds were planted on 4 caged seedspots located on the ROW in 3 replications of poverty grass, rough goldenrod, and hayscented fern.The seedbed conditions tested were:

    A: Seeds planted in litter of undisturbed vegetation (Figure 4).
    B: Seeds placed in exposed mineral soil lying under the plant species tested.
    C: Seeds planted in litter placed over topsoil.
    D: Seeds planted in commercial topsoil.

An important feature of plant competition on undisturbed seedbeds of Treatment A was the presence of a rhizome/root mat that developed near the soil surface under all 3 of the ROW plants investigated (Figure 4). This mat, which is seldom described in ecological literature, is a layer of tangled rhizomes and roots, about 2 inches thick, that can be peeled in an intact mat from the underlying soil. It presents a formidable barrier to tree seedling roots that must penetrate the mat and reach the underlying mineral soil for successful tree establishment.

Black cherry seedspots. Because black cherry was the other common tree species that invaded the ROW, a seedspot study was carried out in 1993 and 1994 similar to that made for red maple. The same dominant ROW plant species were used in these tests. Ninety-five black cherry seeds were planted in each seedspot.

The following treatments were replicated 3 times in pure patches of poverty grass, rough goldenrod, and hayscented fern.

    A: Seeds planted in plant litter of undisturbed vegetation (Figure 4).
    B: Seeds planted in exposed mineral soil lying under the plant species tested.
    C: Seeds planted under plant litter placed over exposed ROW mineral soil.
    D: Seeds planted under a green leaf mulch of the plant species tested placed over ROW mineral soil.
    E: Seeds planted in mineral soil from the adjoining forest.

Results. Germination and height growth on red maple seedspots. At 30 days after seeding, the number of red maple seedlings on mineral soil that laid under ROW plants was significantly higher (p = 0.05) than on the other 3 seedbeds (Figure 6). It was apparent, therefore, that the 3 dominant plant species of the forb-grass cover type had not produced an adverse (toxic) condition capable of significantly inhibiting red maple seed germination.

Red maple seed germination was also higher (p = 0.05) on plant litter over topsoil than on the topsoil control (Figure 6); therefore, it appeared that the litter of the 3 ROW species tested did not contain a toxin capable of significantly reducing tree seed germination.
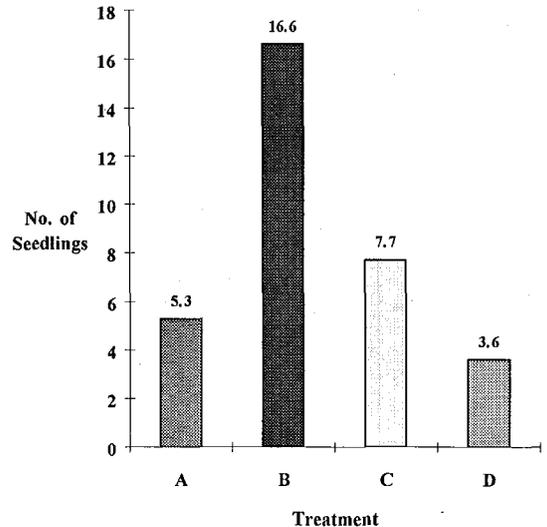

Figure 6. Average number of red maple seedlings per seedspot, 30 days after seeding, for 3 ROW species combined (poverty grass, rough goldenrod, and hayscented fern). Four seedbed treatments were applied in 4 replications: A, undisturbed; B, exposed ROW soil; C, plant litter on topsoil; D, commercial topsoil.

When the average maximum height of red maple seedlings was compared at 75 days after seeding for the 4 different seedbeds tested, there was no significant difference between seedbeds (p = 0.05) (Figure 7). Thus, early height growth was not inhibited by the ROW soil or plant litter produced by the dominant plants typical of the forb-grass cover type.
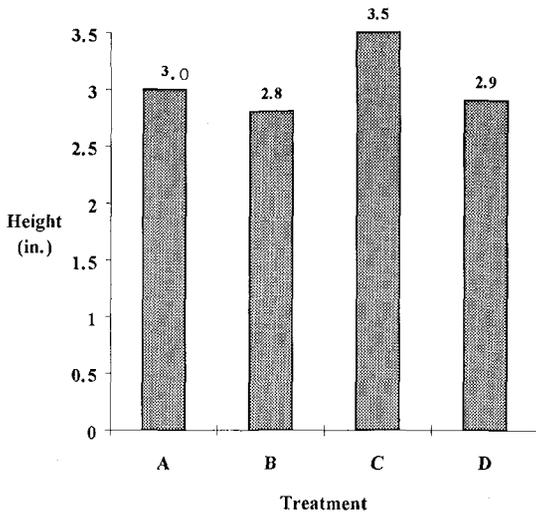
Figure 7. Average maximum height of red maple seedlings on 4 different seedbeds at 75 days after seeding for 3 ROW plant species combined (poverty grass, rough goldenrod, hayscented fern). Treament A, undisturbed; b, exposed ROW soil; C, litter on topsoil; D, commercial topsoil.

Germination and height growth on black cherry seedspots. The importance of a competitive plant cover was further indicated by a low germination of black cherry seed that occurred on undisturbed seedbeds with intact ROW vegetation in contrast to germination on seedbeds at which plants were not present (Figure 8). The 1.9 seedlings per seedspot on those undisturbed seedbeds was significantly less (p = 0.01) than on ROW soil, and under plant litter and green mulch.

Further support for the importance of plant competition was given by the significantly higher black cherry seed germination on important components of the undisturbed seedbeds, namely plant litter and ROW soil, than on the forest soil control (p = 0.05) (Figure 8). Seed germination on the litter over ROW soil seedbed produced 25.9 seedlings per seedspot in contrast to 16.1 on the forest soil.

Maximum heights of black cherry seedlings in 1994 on the 4 seedbeds tested all exceeded heights on the forest soil control. At that time, maximum heights ranged from 2.8 inches on ROW soil to 3.5 inches on ROW soil covered with plant litter. On the forest soil control, the maximum height was 2.5 inches. Thus, it was evident that height growth was not inhibited by ROW soil from under the plants tested or by their litter.
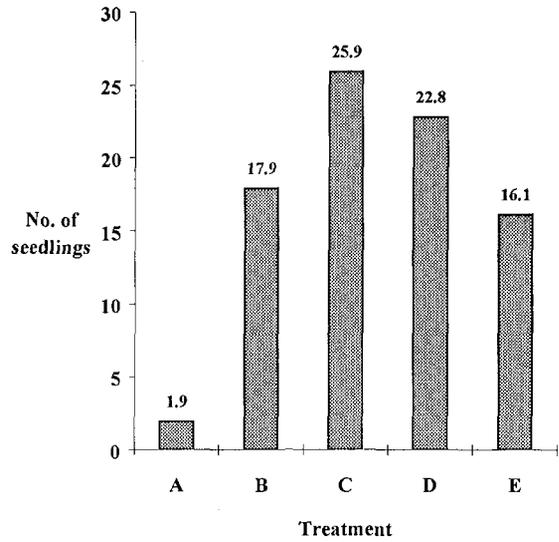

Figure 8. Average number of black cherry seedlings per protected seedspot on 5/29/94 for 3 ROW plant species combined. Five treatments were applied in 3 replications: A, undisturbed; B, ROW soil; C, plant litter on ROW soil; D, green leaf mulch on ROW soil; E, mineral soil from the adjacent forest.

Effect of Plant Competition and Seedbed Condition Under Controlled Conditions

Method. In addition to the 1992 field tests using seedspots, a study was carried out in 1993 under controlled conditions for which soil moisture was provided by watering at 3–5 day intervals. Five seedbeds were replicated 3 times for each of the 3 dominant ROW plants of the forb-grass cover type. Sixteen red maple seeds from one provenance were planted in each seedbed in 4- and 8-inch plastic pots.

The seedbed conditions were:

A: Seeds were planted in the litter of undisturbed vegetation (Figure 4).
B: Seeds were planted in ROW soil in which the plant tested had been growing.
C: Seeds were planted under plant litter on ROW soil from under the plant tested.

D: Seeds were planted under a green mulch composed of leaves and stems of the plant tested that was placed over ROW soil from under the plant.

E: Seeds were planted in mineral soil from the adjoining forest.

Results. Data from these controlled tests in 1993 indicated that, when supplied with adequate soil moisture, red maple seed germination on undisturbed seedbeds with intact plants was not significantly different (p = 0.05) than on soil from the adjacent forest (Figure 9). The same was true for ROW soil and plant litter seedbeds.
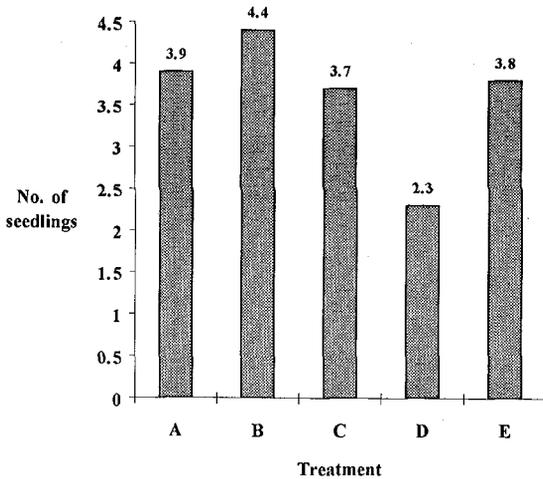

Figure 9. Average number of red maple seedlings per pot for 3 replications of 5 different seedbeds for 3 ROW cover plants combined, at 30 days after seeding. Treatment A, undisturbed seedbed with intact ROW plant; B, ROW soil from beneath ROW plant tested; C, plant litter on ROW soil; D, green leaf mulch on ROW soil; E, soil from the adjacent forest.

Further evidence of the importance of plant competition for soil water was obtained in 1994 through a comparison of red maple seed germination and seedling growth on 3 replicates of an undisturbed seedbed under intact plants of hayscented fern, with similar seedbeds from which fern tops had been removed. Although red maple seed germination was not significantly different when seedbeds were watered at a 3-day intervals, when they were not watered for 7 days, a rapid

drying occurred on seedbeds with intact plants. This drying resulted in a 36% germination in contrast to a 60% germination on seedbeds from which plant tops had been removed. Significant reduction due to drying also occurred in maximum height of red maple seedlings which, at 105 days after seeding on undisturbed seedbeds with intact fern tops, was only 2.1 inches, compared to 3.0 inches on seedbeds from which fern tops had been removed. In summary, the relatively high germination on undisturbed seedbeds composed of litter, humus, and mineral soil indicated that toxic conditions did not exist under hayscented fern.

Although our search for allelopathy was not successful insofar as the natural seedbeds conditions on the ROW were concerned, a green leaf mulch of the ROW plant species significantly reduced (p = 0.05) red maple seed germination (Figure 9). Such green mulch is not naturally present on a ROW, but it can be produced by mowing, a commonly used maintenance treatment.

Conclusions

To summarize our findings on the causes of resistance of the forb-grass cover type to tree invasion, a model was constructed based on data from our investigation (Table 1). Initial invasion of the ROW may be expected to begin with migration of windborne seeds from trees adjacent to the ROW. A formidable barrier to their establishment on the ROW will be wildlife depredation, which caused an 85% loss of seeds in our field tests. Of the surviving red maple seeds, about 57% could

Table 1. Model of the probable fate of 1000 red maple seeds invading a tree-resistant forb-grass cover type on an electric transmission ROW.

Major factors	Loss %	No. seeds per acre
Total # of seeds invading the ROW		1000
Destroyed or pilfered by wildlife	85	850
Remaining after wildlife depredation (Figure 5)		150
Nonviable or dormant seed (germ tests)	57	86
Viable seeds remaining		64
Loss to plant competition (Figure 6)	68	44
Seeds germinating successfully	2	20

be nonviable or dormant according to our germination tests. The remaining viable seeds must compete with established ROW plants for soil water and nutrients. In our tests, plant competition on undisturbed seedbeds with intact plants caused a 68% loss. The net result is that only about 2% of the original 1000 seeds may be expected to produce tree seedlings.

The results of this study indicated clearly that the forb-grass cover type is "tree resistant" not "tree proof." However, such resistance to establishment of trees has been successful in reducing trees to 125 per acre, or less, at 7 years after herbicide applications (6). This reduction in tree invasion is of considerable importance to ROW management as it increases the length of treatment cycles and reduces labor and chemicals required for ROW maintenance.

Finally, of the 3 major interference factors investigated, only wildlife depredation and plant competition appeared to be of importance. Allelopathy was not detected under either field or controlled seedbed conditions (Table 1).

Literature Cited

1. Baker, F.S. 1934. Theory and Practice of Silviculture. 500 pp. McGraw Hill, NY.
2. Bramble, W.C., W.R. Byrnes, and R.J. Hutnik. 1990. *Resistance of plant cover types to tree seedling invasion on an electric transmission right-of-way.* J. Arboric. 16(5): 130–135.
3. Bramble, W.C., R.H. Yahner, and W.R. Byrnes. 1992. *Breeding bird population changes following right-of-way maintenance treatment.* J. Arboric. 18(1): 23–32.
4. Bramble, W.C., R.H. Yahner, W.R. Byrnes, and S.A. Liscinsky. 1992. *Small mammals in plant cover types on an electric transmission right-of-way.* J. Arboric. 18(6): 316–321.
5. Byrnes, W.R., W.C. Bramble, R.J. Hutnik, and S.A. Liscinsky. 1993. Right-of-way site factors responsible for resistance of certain plant cover types to tree invasion. Proc. 5th Symp. on Environ. Concerns in Rights-of-Way Manage., Montreal, Canada. pp. 76–80.
6. Bramble, W.C., W.R. Byrnes, R.J. Hutnik, S.A. Liscinsky, and R.H. Yahner. 1994. Annual Report to Cooperators for the Gamelands 33 Research Project. 37 pp.
7. Brooklyn Botanic Garden. 1991. Natural growth inhibitors: Literature review. Research Report EP-90-14 for Conn. Ed. Company Inc. and Empire State Electric Energy Research Corp. 142 pp.
8. Horsley, S.B. 1977. *Allelopathic inhibition of black cherry by fern, grass, goldenrod, and aster.* Canadian J. For. Res. 7(2): 205–216.
9. Horsley, S.B. 1977. *Allelopathic inhibition of black cherry II: Inhibition by woodland grass, ferns, and clubmoss.* Canadian J. For. Res. 7(3): 515–519.
10. Horsley, S.B. 1990. *Mechanism of interference between hayscented fern and black cherry.* Ecological Society Bulletin. Supplement to Vol. 71, No. 2, p. 193.
11. Putnam, A.R. and C.S. Tang. 1986. The Science of Allelopathy. 317 pp. Wiley, NY.
12. Rice, E.L. 1974. Allelopathy. 353 pp. Academic Press, NY.

Department of Forestry and Natural Resources
Purdue University
West Lafeyette, IN 47907