USING ROUNDUP AND OUST TO CONTROL INTERFERING UNDERSTORIES IN ALLEGHENY HARDWOOD STANDS

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Abstract: Allegheny hardwood stands in the Pennsylvania portion of the type frequently contain dense understories of undesirable species such as hayscented fern (*Dennstaedtia punctilobula* (Michx.) Moore), New York fern (*Thelypteris noveboracensis* L.), grasses and sedges (*Carex* spp.), striped maple (*Acer pensylvanicum* L.) and beech (*Fagus grandifolia* Ehrh.). Once established, they interfere with the establishment of advance regeneration of desirable species. The use of herbicides is a practical means of controlling this vegetation. Initial small-plot studies showed that Roundup controlled all of the undesirable species. Under commercial application conditions, control of vegetation sometimes was less than predicted from the small-plot experiments. Three problems developed as a result of application techniques and subsequent shelterwood cutting in treated stands. First, the use of vehicle-mounted sprayers resulted in regeneration of ferns in the vehicle tracks from small segments of fern rhizome broken off by the treads during herbicide application. When these stands were subsequently shelterwood cut, the fern plants spread rapidly, completely revegetating the stand within a few years. Second, forest floor disturbance created by shelterwood cutting also stimulated germination of grass and sedge seed in the forest floor seed bank, precluding regeneration of desirable hardwoods. Third, striped maple kill was frequently less than expected. The fern, grass, and sedge regeneration problems were solved by using Oust, either alone or tank mixed with Roundup. Control of striped maple was increased by improving coverage of striped maple crowns with Roundup. Current guidelines recommend the use of Oust alone when ferns or ferns and a grass and sedge seed bank are the primary target species. Roundup alone is recommended where striped maple and beech are the primary targets. Where there is a combination of target species, a tank mix of Roundup and Oust is recommended. These herbicides are used in combination with several cutting techniques to obtain regeneration of Allegheny hardwoods.

INTRODUCTION

The cherry-maple or Allegheny hardwood type is a varient of the northern hardwood type found along the Pennsylvania-New York boundary, south through the Appalachians to the

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northern mountains of West Virginia and adjacent areas of Maryland, and in northeastern Ohio. Second- and third-growth stands in this type are composed primarily of black cherry (*Prunus serotina* Ehrh.), red (*Acer rubrum* L.) and sugar maple (*Acer saccharum* Marsh.), white ash (*Fraxinus americana* L.), yellow-poplar (*Liriodendron tulipifera* L.), and beech. In the Pennsylvania portion of the type, more than half of the stands have dense ground covers of herbaceous ferns, grasses and sedges, or woody understories of striped maple and beech root suckers, and are typically difficult to regenerate. Despite the presence of desirable species in the overstory, Allegheny hardwood stands usually lack the knee-high to waist-high regeneration commonly found in other eastern hardwood forest types.

This condition is a result of continuous browsing since the 1920's by a large population of white-tailed deer (*Odocoileus virginianus virginianus* (Boddaert)). Deer browsing has had three effects on forest vegetation: the numbers of seedlings are reduced, surviving seedlings are smaller, and species composition is altered (Marquis and Brenneman 1981; Tilghman 1989). Desirable species such as the maples, ash, and yellow-poplar are highly preferred by deer and tend to be eliminated when they are seedlings. Since black cherry is intermediate in food preference, any large desirable advance regeneration usually is black cherry. The ferns, grasses and sedges, striped maple, and beech are low in food preference and tolerant of understory shade. Thus, they not only remain in the understory but also expand into the growing space formerly occupied by desirable regeneration.

Expansion of undesirable plants also has been encouraged by thinnings which took place in many stands during the late 1950's and 1960's. Rhizome development of hayscented and New York fern and short husk grass (*Brachyelytrum erectum* Schreb.) is greatly accelerated in the partial shade of thinned or shelterwood seed cut stands. Seedlings of striped maple, which can remain in the understory for many years, grow rapidly when additional light is made available. Tolerant beech root suckers sustained by an older root system make surprisingly rapid growth in partially cut stands. Once these undesirable plants occupy the understory, they interfere strongly with the regeneration and establishment of desirable species, even when deer are excluded (Horsley and Marquis 1983). Interference by hayscented and New York fern is particularly serious because they form dense ground covers rapidly and the low intensity, high far-red shade light beneath them results in poor survival of black cherry and other desirable Allegheny hardwood species (Horsley 1986).

When the quantity of interfering plants becomes too great (for guidelines see Marquis et al 1991) steps must be taken to remove them before regeneration can be established. Neither mechanical methods nor fire are effective in the Allegheny hardwood type; however, herbicides are an effective, economical, and safe means of removing interfering plants and minimizing their regeneration so that desirable hardwood species can become established (Horsley et al in press).

Initial small plot studies with several herbicides showed that the herbicide Roundup, manufactured by Monsanto, controlled hayscented and New York fern, short husk grass, and striped maple, and beech, and that the time of application was important in determining the application rate required for effective control (Horsley 1981; Horsley and Bjorkbom 1983). This was particularly true at low rates of application. For example, 95 percent or better control of 1- to 5-foot striped maple could be achieved with 1, 2, or 4 qt/acre of Roundup in early August or early September applications. But, 2-4 qt /acre were required to achieve this level of control if applications were made in early June or early July (Table 1).

Table 1.--Mean percent kill of 1-5 foot striped maple by Roundup applied at different rates and times.[a]

Application Rate	Month of Application				
(qt/acre)	Jun	Jul	Aug	Sep	Oct
1	53 d	81 a-d	95 ab	97 ab	57 cd
2	95 ab	87 abc	97 ab	97 ab	77 bcd
4	97 ab	97 ab	98 ab	99 a	90 ab

[a]Means followed by the same letter were not significantly different or $P \geq 0.05$ using Duncans New Multiple Range Test.

By restricting the application of Roundup to the time between early August and early September, the amount of herbicide needed could be minimized. This is important from both an economic and an environmental standpoint. The same sensitivity to time of application was observed when the 1 qt/acre rate was applied to striped maple stems of increasing size. More than 90 percent control of trees less than 1 foot tall could be obtained with any application date between early June and early October. However, control of larger trees was strongly dependent on application time; optimal control was achieved with early August to early September applications and was less at earlier or later times of application.

Weather conditions early in the growing season affect plant development. Therefore, differences in susceptibility to control by an herbicide can vary due to annual differences in weather conditions. For example, hayscented fern frond development is slower in a cool spring than in a warm spring (Table 2). Thus, early June applications of Roundup made in a year with a cool spring resulted in less control than a similar application in a warm spring.

Sensitivity to timing of Roundup application also was observed at the end of the growing season. When leaf yellowing begins, uptake and translocation of herbicide declines. Roundup applications after this time provided less control of all species we tested. The time of leaf yellowing, which occurs in mid-September in northwestern Pennsylvania, is a practical limit to Roundup application.

Table 2.--Air temperature, hayscented fern frond height, and hayscented fern control by a June 1 application of 1 qt/acre of Roundup.

Year	May Air Temp (°F)			Frond Height (in.)		Fern Control (%)
	Max	Min	Mean	May 1	June 1	
1976[a]	67.7	43.4	55.6	0-2	12	68
1977[b]	77.2	44.5	60.9	1-2	18-24	93

[a]From Climatological Data 81(5):4, Warren, Pennsylvania Station
[b]From Climatological Data 82(5):4, Warren, Pennsylvania Station

Our studies suggest that a high level of plant control can be achieved with 1 qt/acre of Roundup by restricting the time of application. Optimum dates for control of hayscented fern, New York fern, and short husk grass are from early July until leaf yellowing in mid-September. For striped maple, the optimum dates of application are from early August to leaf yellowing and for beech they are from early August to early October.

Once interfering plants are removed, the regeneration process can continue. Where interfering plants are not present, the most important factor determining success of regeneration is the establishment of large numbers of desirable seedlings before the final removal cut (Grisez and Peace 1973). A shelterwood seed cut leaving residual overstory stocking of about 60 percent hastens the development of large numbers of small seedlings (Horsley 1982; Marquis 1979). These seedlings do not grow much because the overstory is still dense enough to provide a light limitation. However, where deer impact is high, this is an advantage because the seedlings are less attractive to deer. Within 3 to 5 years, large numbers of seedlings usually become established, though the process can take longer.

Black cherry and red maple usually predominate in northwestern Pennsylvania stands and the speed with which adequate regeneration develops depends upon the basal area of black cherry greater than 8 inches dbh. Stands with at least 25 square feet of basal area/acre in black cherry usually develop adequate regeneration within a few years after the seed cut; stands with less black cherry often require a longer time. Once adequate regeneration has developed, the remaining overstory can be removed. In stands where herbicide has been applied, the overstory should be removed as soon as adequate regeneration develops to minimize reestablishment of any interfering plants that remain. Concentration of cutting in an area also reduces the impact of deer browsing (Horsley et al in press).

REFINEMENTS IN THE INITIAL PRESCRIPTION

Commercial application of Roundup in an herbicide-shelterwood cut system began in 1979. These applications used air-blast spray equipment mounted on tracked or rubber-tired vehicles. During the first 5 years it became apparent that refinements were required. Three problems developed as a result of application techniques and subsequent shelterwood cutting in treated stands. The first was that ferns were inadequately controlled in the area traversed by the vehicle carrying the sprayer; instead "fern tracks" were formed. Apparently, the metal cleats on tracked vehicles and the sharp edges of new rubber tires break off small segments of fern rhizome at the time of treatment, preventing translocation of Roundup into them. Over a period of 4 to 6 years in shelterwood cut stands, new fern plants regenerate and can reoccupy the understory before desirable hardwood regeneration becomes established. This process is abetted by variable numbers of small, isolated fern plants that develop from single unkilled rhizome buds, probably as a result of incomplete coverage of foliage with herbicide or incomplete translocation of herbicide within the plant.

The second problem was that, following the shelterwood seed cut, the stand sometimes regenerated to grasses and sedges rather than tree seedlings. The forest floor of most Allegheny hardwood stands contains a seed bank of grasses and sedges that germinate after disturbance. The skidding activities associated with the shelterwood seed cut provided the stimulus for germination in disturbed areas (Table 3). The greater the proportion of forest floor that was disturbed, the greater the amount of grass and sedge that developed. Little grass and sedge developed on undisturbed areas, even where a large seed bank was present. Typically, grass and sedge seeds germinated in the growing season after disturbance. Ground cover by these small plants was low in the first year, but during the second growing season after disturbance they grew to full size, greatly expanding in ground coverage. There was little expansion after the second year. Once a grass and sedge ground cover developed, the regeneration process was slowed so dramatically that little regeneration became established under our conditions that include an extremely high deer population.

Table 3.--Mean percent ground cover by newly germinated grass and sedge on disturbed and undisturbed plots 1, 2 and 3 years after disturbance.[a]

Disturbance	Years after Treatment		
	1	2	3
	------(%)------		
Roulette			
Disturbed	13[b] ± 20 a	0.4 ± 0.5 bcd	0 ± 0.2 bd
Undisturbed	1 ± 2 bc	0.4 ± 0.5 bcd	0 ± 0.3 bd
Kane			
Disturbed	43 ± 28 a	1 ± 0.6 b	
Undisturbed	2 ± 2 b	1 ± 1 b	

[a]Disturbance by year after treatment means at a location followed by the same letter were not significantly different at $P \geq 0.05$ using the Bonferroni procedure. Each value is shown ± one standard deviation. n = 63.
[b]Each disturbance by year after treatment value is the mean of 21 observations.

The third problem was that, under commercial operating conditions, striped maple stems were not always controlled by Roundup as well as might be predicted from small-plot experiments.

Stems were almost always defoliated, but some were not killed and refoliated the following year from unkilled axillary buds. Increasing the rate of Roundup application from 1 to 4 qt/acre resulted in complete striped maple kill, but at an unacceptibly high cost.

The problems of "fern track" and grass and sedge reinvasion were solved by the inclusion of the residual herbicide Oust, manufactured by Du Pont, in tank mix with Roundup. A rate and time experiment to evaluate the effectiveness of Roundup in tank mix with Oust and Surflan in minimizing reestablishment of grass and sedge on disturbed sites showed that 2 to 4 oz/acre of Oust or 2 to 4 qt/acre of Surflan reduced reinvasion by grass and sedge originating in the forest floor seed bank for 2 or 3 years, respectively (Horsley, 1990b). Oust now has an EPA registration for this use, Surflan does not.

The study also pointed out that on sites where grass and sedge seed banks were large, herbicide alone was inadequate for reducing reinvasion and that steps were required to reduce the amount of forest floor disturbance on these sites. Another rate and time experiment with Oust alone showed that 2 oz/acre provided nearly complete control of hayscented and New York fern when applied between early July and early October (Table 4) (Horsley 1988).

Table 4.--Percent control of hayscented and New York fern and short husk grass 2 years after treatment with 2, 4, or 8 oz/acre of Oust. Oust was applied at the beginning of each month. Untreated control plots with which treated plots were compared had 100 percent ground cover by the target species.[a]

Rate of	Month of Application						
Application	May	Jun	Jul	Aug	Sep	Oct	Nov
Hayscented and New York Fern							
1	9 gh	52 def	98 ab	98 ab	98 ab	97 ab	27 fg
2	40 f	68 cde	99 a	98 ab	97 ab	98 ab	42 ef
3	75 cd	87 gh	100 a	99 a	99 a	99 a	69 cd
Short Husk Grass							
1	0 h	0 h	1 gh	1 gh	10 defg	2 fgh	6 efgh
2	0 h	0 h	10 defg	3 fgh	23 cde	18 def	10 defg
3	0 h	22 cde	50 ab	48 abcd	70 a	31 bcd	53 ab

[a]Month by rate of application means for each species followed by the same letter were not significantly different at $P \geq 0.05$ using the Bonferroni procedure.

Applications of Oust made earlier or later than these dates provided less control and results were rate-dependent. Oust did not provide adequate post emergent control of mature short husk grass plants, regardless of the rate (2 to 8 oz/acre) or time (early May to early November) of application (Table 4), nor did it have any effect on striped maple or beech (data not shown).

Efforts to increase the activity of Roundup on striped maple by the addition of adjuvants or other herbicides into the tank mix showed that none gave better results than Roundup alone (Table 5) (Horsley 1990a). Addition of adjuvants such as ammonium sulfate or EDTA to remove hard water ions that might bind the glyphosate molecule did not increase Roundup activity. Adjuvants that increase herbicide wetting and penetration of leaves, such as X-77 Spreader, Frigate Agricultural Adjuvant, and Sorbicide Herbicide Adjuvant, also did not increase control of striped maple above that obtained with Roundup alone. Inclusion of Sorbicide reduced herbicide effectiveness. Tank mixing Escort with Roundup gave the same results as Roundup alone, and a tank mix of 2,4-D amine with Roundup resulted in less control of striped maple than Roundup alone.

Table 5.--Mean percent kill of 5 - 20 foot tall striped maple stems by Roundup plus adjuvants and other herbicides 2 years after application.[a]

Herbicide Treatment	Percent Kill
Roundup (Control)[b]	81 a
Roundup + 1% EDTA	75 a
Roundup + 0.93% Ammonium Sulfate	71 a
Roundup + 1% Sorbicide Herbicide Adjuvant	51 b
Roundup + 0.5% Frigate Agricultural Adjuvant	86 a
Roundup + 0.5% X-77 Spreader	79 a
Roundup + 1 pt 2,4-D amine	65 b
Roundup + 1/4 oz Escort	70 a
Roundup + 1/2 oz Escort	70 a

[a]Percent kill means followed by the same letter were not significantly different at $P \geq 0.05$ using the Bonferroni procedure.
[b]Roundup was applied at the rate of 1 qt/acre in all treatments.

The most important factor controlling the proportion of striped maple stems killed by Roundup was distribution of the herbicide. The dilemma in ground spray operations with most air-blast spray equipment currently used in the Allegheny hardwood region is that the sprayer volute only allows the main blast of spray to be directed to vegetation in a limited vertical space. Aiming the volute horizontally results in good coverage of vegetation up to about 10 feet in height. Aiming the volute at an upward angle results in good coverage of vegetation from about 5 to 20 feet in height. Shorter vegetation is not well covered because much of the spray is intercepted by the larger vegetation.

Recently, Hammermill (International) Paper Co. purchased a Friend air-blast sprayer. The volute on the Friend has a vertical stack of nozzles that fills the air space with spray from the ground to a height of about 20 feet. Exceptionally good control of both short and tall vegetation in this space has been obtained in commercial spray operations using 1 qt/acre of Roundup in 25 gallons of water.

ECONOMIC CONSIDERATIONS

The decision to use herbicide in Allegheny hardwood stands is triggered by understory stocking (more than 30 percent) with ferns, grasses and sedges, striped maple, or beech (Marquis et al 1991). From a biological standpoint, Oust will effectively control ferns and will provide preemergent reduction of ground cover by grasses and sedges originating from the forest floor seed bank on disturbed areas. Oust has no activity on striped maple or beech. Roundup will control all of the interfering plants present in Allegheny hardwood stands but it has no residual soil activity, and will not provide preemergent control of grass and sedge originating in the forest floor seed bank after soil disturbance.

In commercial operations, fern tracks also are a problem when Roundup is used alone. In stands with ferns alone or with ferns and a grass and sedge seed bank, Oust provides the most effective control at the least cost. In stands with interfering striped maple and/or beech understories, Roundup is the herbicide of choice. Roundup should be applied at the rate of 1 qt/acre and Oust at the rate of 2/acre. Most stands have a combination of ferns, grasses and sedges, striped maple, and beech. In these, Roundup and Oust should be tank mixed with 0.5 percent of a non-ionic surfactant, such as X-77 or Frigate. When a combination of interfering plants is present, the decision to use one herbicide or a tank mix is an economic one based on the stand value at maturity lost by not adding the second herbicide to control interfering plants not controlled by the first herbicide. For example, let us assume that the cost of applying a single herbicide, including both the chemical and application costs, is $100/acre and that the cost of adding a second herbicide brings the total cost to $115/acre. Furthermore, let us assume that Allegheny hardwood stands are managed on an 80-year rotation, have values ranging between $1000 and $5000/acre at that age, and that real (no inflation, no after-inflation increase in timber prices) interest rates range from 3.5-5 percent. Under these conditions, the difference in discounted cost between using one and using two herbicides is $235/acre at 3.5 percent interest and $743/acre at 5 percent interest over 80 years. For stands valued at $5000/acre, $250/acre is lost for every 5 percent of stand area lost to plants not killed by the first herbicide; for stands valued at $1000/acre, $50 is lost for every 5 percent of the stand area lost to plants not killed by the first herbicide. A high-value stand ($5000/acre at maturity) needs less than 5 percent of the area covered by unkilled interfering plants to warrent use of the second herbicide if the interest rate is 3.5 percent, or 15 percent of the area covered by unkilled interfering plants to warrent use of the second herbicide if the interest rate is 5 percent. Comparable values for a low-value stand ($1000/acre at maturity) are 23 percent and 75 percent, respectively. Consideration of the wide range of conditions encountered in the Allegheny forest region suggests that the second herbicide should be added when more than about 15 percent of the regeneration sample plots have interfering plants that would not be killed by the first herbicide.

COMBINING HERBICIDE WITH CUTTING PROCEDURES

In most cases, herbicide is sprayed in the uncut stand, followed by a shelterwood seed cut. However, where large grass and sedge seed banks are present, herbicide alone was not effective in preventing revegetation of the site (Horsley 1990b). Reducing the amount of disturbance in addition to using herbicide is required in this situation. Modifying the herbicide and cutting sequence used to regenerate the stand is an effective way to minimize grass and sedge regeneration. Since shelterwood cutting is the primary source of disturbance that stimulates grass and sedge regeneration, reversing the herbicide and cutting sequence (shelterwood seed cut then herbicide) induces grass and sedge regeneration before the herbicide is applied. The herbicide removes these interfering plants. Since no more disturbance occurs in the stand, regeneration develops unhindered. When this procedure is used, steps must be taken to keep slash close to the ground so that it does not interfere with movement of the sprayer in the stand.

Another alternative is to delay any cutting in the stand until regeneration is established, then make the final removal cut. This procedure is useful in stands with less than 75 percent overstory stocking, since there is enough light to allow desirable seedling establishment. It also avoids soil disturbance which might allow interfering plants such as grasses and sedges to recapture the stand before regeneration becomes established. When the final removal cut is made, the well-established tree seedlings rapidly outgrow any interfering plants that have developed.

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