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Manual Herbicide Application Methods for Managing Vegetation in Appalachian Hardwood Forests

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Cover photos

Front cover: Stem injection on a cull tree using the hack-and-squirt method. Photo by James N. Kochenderfer, U.S. Forest Service (ret.).

Back cover: Four primary application methods used in the central Appalachians. Clockwise from upper left: stem injection, foliar spray, cut-stump treatment, and basal spray. Upper left, upper right, and lower right photos by James N. Kochenderfer, U.S. Forest Service (ret.). Lower left photo by Jeffrey D. Kochenderfer, U.S. Forest Service.

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CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife—if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

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INTRODUCTION

Forestry herbicides are a versatile, cost-effective tool that can be used in a variety of ways to help manage forest vegetation. Managing forests to grow selected crop trees is similar to growing agriculture crops: there are usually undesirable plants or weeds present that interfere with desirable crop plants. In agriculture, weeds are controlled by various vegetation management practices, including the use of herbicides, to increase the availability of site resources for desirable crops. In forestry, herbicides can also be used to control undesirable plants so that sunlight, soil moisture, and nutrients are concentrated on desirable crop trees.

Species composition is a key consideration in hardwood forests because the value of individual tree species often varies widely. High-value timber species might represent a relatively low percentage of trees in a forest stand yet a very high percentage of total stand value. A crop tree field guide that discusses timber, wildlife, and aesthetic values for 16 common tree species has been developed for central Appalachian forests to help land managers make more informed decisions regarding crop tree selection. Some species like northern red oak (*Quercus rubra* L.) and black cherry (*Prunus serotina* Ehrh.) are desirable for both timber and wildlife value. They are considered two of the most valuable timber and wildlife species in the central Appalachians. Although surveys frequently indicate the primary reason that individuals own forestland is for non-timber woodland benefits, forest landowners are often interested in growing valuable timber

crop trees to help offset management costs and to enhance long-term returns on their investment.

Forestry herbicides can be used in a variety of ways to manage forest vegetation to provide a competitive advantage to selected desirable trees or seedlings that will enable them to grow into valuable crop trees. They can also be used to prepare sites for planting or natural regeneration and to reduce competition around newly planted seedlings to increase their growth and survival. Controlling interfering understory and midstory vegetation with herbicides to promote desirable regeneration like black cherry and northern red oak is becoming more widespread in the Appalachians. Other opportunities for herbicide use include managing vegetation on forest roads and creating and maintaining wildlife habitat. However, timber stand improvement operations involving the release of existing crop trees from similar sized competing trees and controlling large cull trees left from previous harvests probably provide the greatest opportunities to use herbicides in Appalachian hardwood forests. A wealth of research information indicates that crop tree release is a cost-effective way to increase the future value of hardwood stands. The cost and difficulty of establishing new desirable reproduction in forests make it easier to justify expenditures in vegetation management to maintain and enhance the growth of existing desirable trees.

Although numerous studies have demonstrated that modern herbicides can be safely applied in forests, some people still have concerns about their use. Forestry herbicides inhibit

biochemical pathways that are specific to plants. Commonly used and recommended forestry herbicides are very low in animal toxicity and do not bioaccumulate. Because of their low toxicities and minimal environmental hazards, most herbicides used in forestry operations are classified as "non-restricted use," meaning they are available to the general public and no license is required for landowners to buy them and apply them on their own land. Normally only small amounts of forestry herbicides are applied during treatments with long time intervals (years) between applications. Research has shown that herbicides used in forestry biodegrade relatively fast after application. According to monitoring studies, leaving untreated buffer zones around water sources insures that they will be protected. Herbicide labels, which contain a description of the herbicides, safety recommendations, and detailed use information, are the user's primary source of information regarding the safe and legal use of herbicides. Always read and follow all of the label instructions.

Manual herbicide application methods are especially suited for the small forest ownerships in the rugged Appalachians, where the use of mechanical methods is often limited by steep terrain. Most wood in the eastern hardwood region is currently harvested on nonindustrial private forestland and this amount is expected to increase. Several manual application techniques are very target-specific, meaning they can be used to control undesirable vegetation without impacting nontarget plants like desirable advance regeneration or valuable crop trees. Private landowners are reluctant to use vegetation management methods that might impact a neighbor's property. Since using

correct manual herbicide application techniques requires minimal training and equipment, landowners can often perform herbicide applications on their own property. Using herbicides in timber stand improvement operations has some decided advantages over mechanical methods. Applying herbicide treatments to control individual trees is safer for most people to do than mechanical methods like girdling or chainsaw felling. The boles of treated trees controlled with herbicides are not structurally weakened as much by herbicide treatments as they are by girdling. The branches and twigs of the dead trees usually fall gradually, minimizing stand damage, while the boles often stand for long periods and provide valuable habitat for wildlife. Cutting and girdling will not control stump and root sprouts and often stimulate their development, thus making competition worse.

The purpose of this manual is to provide practical information that will enable forest landowners and others to correctly and safely use some common herbicides to manage forest vegetation in the central Appalachians. Most vegetation management problems in Appalachian hardwood forests can be addressed by using a small number of herbicides and manual application techniques. If additional information beyond the scope of the manual is desired, the reader should consult the publications listed in the Sources of Information section. When needed, additional help and advice can be obtained from other qualified sources, such as consulting foresters, local extension agents, chemical company representatives, herbicide distributors, and state agencies and universities.

The herbicides described in this field manual are produced by a variety of manufacturers. Trade names are used throughout the text for clarity, although generic formulations with identical efficacy may be available. The trade names used in this manual with the manufacturer in parentheses are as follows: Accord® (Dow Agro Sciences, Indianapolis, IN), Arsenal® (BASF Specialty Chemicals, Research Triangle Park, NC), Cide-Kick® (Brewer International, Vero Beach, FL), Garlon® (Dow Agro Sciences, Indianapolis, IN), Glyphomate® (PBI/Gordon Corp., Kansas City, MO), Oust® (DuPont, Wilmington, DE), Razor® Pro (Nufarm Specialty Products, Burr Ridge, IL), and Roundup Pro® (Monsanto, St. Louis, MO).

The following four sections contain a series of photographs and tables that illustrate field procedures and provide information on the use of the four primary manual application methods used in the central Appalachians: 1) stem injection, 2) basal spray, 3) cut-stump, and 4) foliar spray.

SECTION I:
STEM INJECTION SUMMARY

- Use 38-percent solution of Accord® Concentrate in a water carrier.
- Use 50-percent solution of Garlon® 3A, Roundup Pro®, Glyphomate®, or Razor® Pro in a water carrier.
- Use 6-percent solution of Arsenal® or 3-percent solution of Arsenal® AC in a water carrier.
- Arsenal® herbicide is very effective on maple (*Acer* spp.).
- Make one incision per inch of diameter at breast height (d.b.h.) spaced evenly around the stems.
- Apply 1.5 milliliters (ml) (0.05 oz.) of solution per incision.
- Treatment is applicable to stems ≥1.0 inch d.b.h.
- The "cut stub" treatment (Figure 14) is very effective on stems smaller than 1.0 inch d.b.h.
- Treatment is best applied from June 1 to November 1.
- Do not apply during periods of heavy sap flow (February through May).
- Treatment costs $50-$75 per acre (chemical and labor).

James N. Kochenderfer, U.S. Forest Service (ret.)

Figure 1.—Mixing herbicide solutions for a crop tree release operation. This worker is wearing personal protective equipment listed on the herbicide label. Other useful tools include a pocket calculator, graduated cylinder, and funnel.

James N. Kochenderfer, U.S. Forest Service (ret.)

Figure 2.—Stem injection materials: spray bottle, labeled bottle of herbicide solution, herbicide label, Material Safety and Data Sheet (MSDS), container of wash water, and sharp hatchet with a ground-down bit 1.75 inches wide. Note that all containers are labeled, including the one containing wash water.

James N. Kochenderfer, U.S. Forest Service (ret.)

Figure 3.—Applying herbicide to incision. To make a good incision, chop through the bark into the wood at an angle to make a cuplike incision; then bend the hatchet head down by twisting your arm to open the incision. Leaving the hatchet blade in the incision, squirt herbicide directly into the incision. Do not overfill incisions because any herbicide that runs out is wasted and might impact nontarget plants. When defective incisions will not hold herbicide, make additional incisions next to them. In difficult-to-control species like black gum (*Nyssa sylvatica* Marsh), hickory (*Carya* spp.), red maple (*Acer rubrum* L.), and large cull trees, space incisions closer or add a few incisions at the base of the tree where large roots are attached to the trunk to increase efficacy.

James N. Kochenderfer, U.S. Forest Service (ret.)

Figure 4.—An applicator injecting a cull tree using a hatchet with a ground-down bit and a spray bottle with a 50-percent solution of Razor® Pro herbicide in a water carrier. This tree injection method is called hack-and-squirt. It is usually considered one of the cheapest manual application methods. Use 1.5 milliliters (ml) of solution per inch of tree d.b.h. in incisions spaced evenly around the tree. Spray bottles do not all spray the same amount per pull, but they can be readily calibrated. Fill the spray bottle with water and use a complete pull to squirt 10 times into a graduated cylinder and then determine the average volume dispensed with each complete pull. The spray bottle shown here dispenses 2.8 ml per complete pull, so it requires about one-half pull per incision.

James N. Kochenderfer, U.S. Forest Service (ret.)

Figure 5.—Injecting a black gum using a hatchet and gunjet herbicide gun attached to a backpack sprayer containing a 50-percent solution of Glyphomate®. This equipment enables workers to inject numerous trees without refilling the sprayer tank. Herbicide guns equipped with an adjustable nozzle and using low pressure make it easier to squirt herbicide solutions into incisions. They are very durable and cost less than $100. Applicators normally do not carry much more than a gallon of solution at a time in their sprayers.

James N. Kochenderfer, U.S. Forest Service (ret.)

Figure 6.—Crown of a beech tree (*Fagus grandifolia* Ehrh.) 3 weeks after being injected with a 50-percent solution of Roundup Pro® in a water carrier. Herbicide migrates within the plant from the point of application to the most actively growing parts of the plant.

James N. Kochenderfer, U.S. Forest Service (ret.)

Figure 7.—A northern red oak sapling responding to release from a competing cull tree that was injected several years ago using a 38-percent solution of Accord® Concentrate in a water carrier.

James N. Kochenderfer, U.S. Forest Service (ret.)

Figure 8.—Tree injection in a yellow-poplar (*Liriodendron tulipifera* L.) stand using a 50-percent solution of Garlon® 3A in a water carrier to release a yellow-poplar crop tree from other competing yellow-poplar trees. Since functional root grafts are often formed between roots of the same species, Garlon® 3A was used because triclopyr, the active ingredient, is not translocated well in plants and will not impact nearby yellow-poplar trees. However, injecting competing trees attached to the same stump as crop trees is not recommended. A 5-foot buffer between crop trees and treated trees of the same species is recommended with use of glyphosate herbicides, the most commonly used herbicides in crop tree release operations. Arsenal® AC is not recommended for crop tree release operations because damage can occur to nontarget plants. Imazapyr, the active ingredient, exhibits soil activity and can be absorbed by the roots of nontarget plants. However, reduced concentrations of Arsenal® (Figure 10) can be used to inject scattered cull trees and small understory trees of species different from nearby desirable trees.

Jeffrey D. Kochenderfer, U.S. Forest Service

Figure 9.—Basal sprouts on a top-killed striped maple (*Acer pensylvanicum* L.) that had been injected with a 50-percent solution of Razor® Pro. Some trees, especially maples, are prone to resprouting after being injected with glyphosate herbicides.

James N. Kochenderfer, U.S. Forest Service (ret.)

Figure 10.—Dead striped maple injected with a 9-percent solution of Arsenal® in a water carrier around an undamaged black cherry tree. Subsequent herbicide trials have shown that injecting striped maple with a more dilute 6-percent solution of Arsenal® (or 3-percent Arsenal® AC) effectively controlled injected striped maple stems with no resprouting or damage to desirable trees. Using these lower herbicide concentrations and restricting treatment to species different from those considered desirable for crop trees will minimize damage to desirable species.

James N. Kochenderfer, U.S. Forest Service (ret.)

Figure 11.—A research plot in a northern hardwood stand showing results of treatment of beech trees with Arsenal®. Understory and midstory beech trees 1 to 10 inches d.b.h. (flagged trees) were injected using a 6-percent solution of Arsenal® in a water carrier, which is equivalent to a 3-percent solution of Arsenal® AC, to promote the establishment of desirable regeneration. This treatment controlled a majority of untreated beech root sprouts. All of the injected stems were controlled and no desirable overstory trees were damaged by this treatment. Restricting treatment to only beech stems precluded herbicide transmission to other species by root grafts. Response to Arsenal® herbicide treatments is delayed; complete effectiveness does not appear until the second growing season after treatment.

Jeffrey D. Kochenderfer, U.S. Forest Service

Figure 12.—A northern hardwood stand where beech understory stems 1 to 11 inches d.b.h. were injected 3 years ago with a 50-percent solution of Razor® Pro in a water carrier to regenerate shade-intolerant black cherry. Treatment efficacy was similar to that observed in the Arsenal® treatment shown in Figure 11. However, the Arsenal® treatment would be the best option when there is a significant component of striped maple in the understory.

James N. Kochenderfer, U.S. Forest Service (ret.)

Figure 13.—Underplanted eastern white pine (*Pinus strobus* L.) released from overtopping hardwoods using the hack-and-squirt procedure and a 3-percent solution of Arsenal® AC in a water carrier.

Jeffrey D. Kochenderfer, U.S. Forest Service

Figure 14.—Treatment of small stems. Trees less than 1 inch d.b.h. are too small to inject properly. An effective way to treat small stems during weeding operations is to cut competing stems like this small beech using a Swedish brush ax and then spray the cut stubs of undesirable species with the same concentration of a glyphosate herbicide as used in the hack-and-squirt treatments. This ax can also be used to make incisions on smaller trees that are < 8 inches d.b.h.

Table 1.—How to prepare various herbicide solutions for stem injection vegetation control treatments

Desired herbicide solution concentration	Chemical name (percent active ingredient)	Herbicide component	Carrier component	All Components[a]	Reference
38-percent Accord® Concentrate	Glyphosate (53.8-percent a.i.)	1,438 ml (49 oz.) chemical	2,347 ml (79 oz.) water	3,785 ml or 1 gallon	Figure 7
50-percent Roundup Pro®	Glyphosate (41.0-percent a.i.)	1,893 ml (64 oz.) chemical	1,892 ml (64 oz.) water	3,785 ml or 1 gallon	Figure 6
50-percent Glyphomate®	Glyphosate (41.0-percent a.i.)	1,893 ml (64 oz.) chemical	1,892 ml (64 oz.) water	3,785 ml or 1 gallon	Figure 5
50-percent Razor® Pro	Glyphosate (41.0-percent a.i.)	1,893 ml (64 oz.) chemical	1,892 ml (64 oz.) water	3,785 ml or 1 gallon	Figures 4, 9, 12
50-percent Garlon® 3A	Triclopyr (44.4-percent a.i.)	1,893 ml (64 oz.) chemical	1,892 ml (64 oz.) water	3,785 ml or 1 gallon	Figure 8
6-percent Arsenal®	Imazapyr (28.7-percent a.i.)	227 ml (8 oz.) chemical	3,558 ml (120 oz.) water	3,785 ml or 1 gallon	Figures 10, 11
3-percent Arsenal® AC	Imazapyr (53.1-percent a.i.)	114 ml (4 oz.) chemical	3,671 ml (124 oz.) water	3,785 ml or 1 gallon	Figures 10, 11, 13

[a] Agitate well.

FIELD NOTES FOR STEM INJECTION

SECTION II:
BASAL SPRAY SUMMARY

- Use 10- to 20-percent mixture of Garlon® 4 in an oil carrier (10-percent mixture on thin-bark species).
- See herbicide label for recommended oil carriers.
- Spray completely around stems 12-15 inches above groundline to point of runoff.
- Treatment is applicable to stems <6.0 inches d.b.h. and treatments involving <1,000 stems per acre.
- Apply any time of the year stems are dry.
- Treatment costs $80-$125 per acre depending on the number of stems treated (chemical and labor).

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Figure 15.—Basal bark spraying small beech stems 12-15 inches above the groundline using a backpack sprayer with a 10-percent mixture of Garlon® 4 and oil. Target stems must be dry, free of snow to the groundline, and completely wetted on all sides with the spray mixture. Basal spraying is a very effective treatment on small stems <6 inches d.b.h., but it can require carrying large volumes of solution on steep topography and it normally costs more than tree injection treatments. Basal spraying is especially adapted for treating relatively low numbers of small, thin-bark species like beech and striped maple because they require less spray, and lower concentrations of spray (10-percent Garlon® 4) are effective.

James N. Kochenderfer, U.S. Forest Service (ret.)

Figure 16.—Beech understory basal sprayed with a 10-percent mixture of Garlon® 4 and oil. Garlon® 4 basal spray treatments are effective only on treated stems; triclopyr is not translocated to untreated stems. Basal spraying large numbers of small stems is costly and generally not recommended.

James N. Kochenderfer, U.S. Forest Service (ret.)

Figure 17.—Striped maple basal sprayed with a 10-percent mixture of Garlon® 4 and oil. This treatment resulted in a very high efficacy with no resprouting.

James N. Kochenderfer, U.S. Forest Service (ret.)

Figure 18.—Fifteen-foot tall clumps of autumn olive (*Elaeagnus umbellata* Thunb.) 2 weeks after basal spraying with a 10-percent solution of Garlon® 4 and oil. Tall shrubs that grow in clumps like autumn olive and witch hazel (*Hamamelis virginiana* L.) are difficult to inject or foliar spray but lend themselves well to this treatment.

Table 2.—How to prepare various herbicide solutions for basal spray vegetation control treatments

Desired herbicide solution concentration	Chemical name (percent active ingredient)	Herbicide component	Carrier component	All components	Reference
10-percent Garlon® 4 Ultra	Triclopyr (60.5-percent a.i.)	379 ml (13 oz.) chemical	3,406 ml (115 oz.) oil	3,785 ml or 1 gallon	Figures 15, 16, 17, 18
20-percent Garlon® 4 Ultra	Triclopyr (60.5-percent a.i.)	757 ml (26 oz.) chemical	3,028 ml (102 oz.) oil	3,785 ml or 1 gallon	

FIELD NOTES FOR BASAL SPRAY

SECTION III:
CUT-STUMP TREATMENT SUMMARY

- Use 50- to 100-percent glyphosate herbicide product in a water carrier.
- Use 3-percent Arsenal® AC or 6-percent Arsenal® in a water carrier.
- Treat stumps as soon as possible after cutting, although treatment can be effective on beech in the central Appalachians up to 4 days after cutting.
- Spray outer 2 inches of stump surface.
- Treatment is effective on all sizes of stumps.
- Root sprout mortality is greater around larger stumps.
- Do not use this treatment when stumps and nearby desirable trees are the same species.
- Treatment is best applied from June 1 to November 1.
- Do not apply during heavy sap flow (February through May).
- Treatment costs $40-$60 per acre (chemical and labor).

James N. Kochenderfer, U.S. Forest Service (ret.)

Figure 19.—A dense beech understory that will interfere with the regeneration of high-value species. The cut-stump treatment can be used as a site preparation treatment to promote the establishment and development of desirable species and to release established regeneration.

James N. Kochenderfer, U.S. Forest Service (ret.)

Figure 20.—Beech root sprouts attached to a beech parent tree root. Most beech regeneration originates from root sprouts. Glyphosate® herbicides are readily translocated from the surfaces of freshly cut beech stumps to attached root sprouts via parent root systems.

James N. Kochenderfer, U.S. Forest Service (ret.)

Figure 21.—Applying the cut-stump treatment to a freshly cut beech stump using a 50-percent solution of Razor® Pro in a water carrier. Brush the sawdust from the stumps before treatment. Using a glyphosate herbicide that contains a surfactant or adding a nonionic surfactant is often recommended to increase penetration. It is necessary to wet only the outer 2 inches around larger stump surfaces; the entire surface of small stumps is treated.

James N. Kochenderfer, U.S. Forest Service (ret.)

Figure 22.—Applying the cut-stump treatment using a spray bottle to dispense herbicide on a freshly cut beech stump. Although it is usually recommended that this treatment be applied to stump surfaces as quickly as possible after cutting, recent research indicates that waiting up to 4 days after partial cutting before treating beech stumps with a 50-percent solution of Razor® Pro in a water carrier did not significantly reduce root sprout or stump sprout efficacy in a partially cut Appalachian stand.

James N. Kochenderfer, U.S. Forest Service (ret.)

Figure 23.—Stumps after treatment with a glyphosate herbicide. They turn yellow within 1 hour after treatment.

James N. Kochenderfer, U.S. Forest Service (ret.)

Figure 24.—Beech stumps treated with a glyphosate herbicide containing dye. Using a dye recommended for use with glyphosate to enhance the coloration, makes it easier to keep track of treated stumps. It is necessary to wet only a 2-inch band encompassing the cambium layer on larger stumps while the entire surface of smaller stumps is sprayed.

James N. Kochenderfer, U.S. Forest Service (ret.)

Figure 25.—Untreated beech stumps showing uncontrolled beech root sprouts and the development of new beech root sprouts stimulated by a timber harvest.

Jeffrey D. Kochenderfer, U.S. Forest Service

Figure 26.—Beech root sprout mortality around beech stumps treated with a 50-percent solution of Roundup Pro® herbicide in a water carrier to promote the establishment and development of desirable regeneration. Garlon® 3A and Garlon® 4 are not recommended for the cut-stump treatment on root-sprouting species because triclopyr, the active ingredient in these herbicides, is not translocated well to attached sprouts. Do not use the cut-stump treatment if desirable trees of the same species being treated are nearby (within 50 feet) because transmission of herbicide through root grafts could occur.

Jeffrey D. Kochenderfer, U.S. Forest Service

Figure 27.—Northern red oak seedlings being planted in the spring among beech stumps that were treated the previous fall with a cut-stump treatment using a 50-percent solution of Glyphomate® herbicide in a water carrier.

James N. Kochenderfer, U.S. Forest Service (ret.)

Figure 28.—Live white pine (*Pinus strobus* L.) and northern red oak saplings surrounded by dead beech root sprouts. Treating large numbers of individual small stems with herbicides can be very costly. The cut-stump treatment enables large numbers of small stems to be controlled by treating one large stem. Since glyphosate herbicides have no soil activity and the cut-stump treatment affects only the same species as that being treated, existing advance regeneration of other desirable species is not impacted by this treatment.

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Figure 29.—Stump sprouts developing on an untreated beech stump. Spraying the exposed bark on cut stumps with Garlon® 4 in an oil carrier will control stump sprouting.

James N. Kochenderfer, U.S. Forest Service (ret.)

Figure 30.—Control of stump sprouts on a beech stump after cut-stump treatment. This treatment will control stump sprouts on many species. It is especially effective on root-sprouting species such as beech, black gum, sassafras (*Sassafras albidum* Nutt. Nees), and tree-of-heaven (*Ailanthus altissima* (Mill.) Swingle), where it controls both stump and root sprouts. Spraying the outer 2 inches of freshly cut stump surfaces with water-soluble herbicides containing the active ingredients glyphosate or imazapyr, which are both readily translocated to attached root sprouts, will provide good control of both stump and root sprouts.

Table 3.—How to prepare various herbicide solutions for cut-stump vegetation control treatments

Desired herbicide solution concentration	Chemical name (percent active ingredient)	Herbicide component	Carrier component	All components	Reference
50-percent Roundup Pro®	Glyphosate (41.0-percent a.i.)	1,893 ml (64 oz.) chemical	1,892 ml (64 oz.) water	3,785 ml or 1 gallon	Figures 26, 28, 30
50-percent Glyphomate® 41	Glyphosate (41.0-percent a.i.)	1,893 ml (64 oz.) chemical	1,892 ml (64 oz.) water	3,785 ml or 1 gallon	Figures 27, 28, 30
50-percent Razor® Pro	Glyphosate (41.0-percent a.i.)	1,893 ml (64 oz.) chemical	1,892 ml (64 oz.) water	3,785 ml or 1 gallon	Figures 21, 22, 28, 30
6-percent Arsenal®	Imazapyr (28.7-percent a.i.)	227 ml (8 oz.) chemical	3,558 ml (120 oz.) water	3,785 ml or 1 gallon	Figure 30
3-percent Arsenal® AC	Imazapyr (53.1-percent a.i.)	114 ml (4 oz.) chemical	3,671 ml (124 oz.) water	3,785 ml or 1 gallon	Figure 30
10-percent Garlon® 4 Ultra	Triclopyr (60.5-percent a.i.)	379 ml (13 oz.) chemical	3,406 ml (115 oz.) oil	3,785 ml or 1 gallon	Figure 29

FIELD NOTES FOR CUT-STUMP TREATMENT

SECTION IV:
FOLIAR SPRAY SUMMARY

- Use 1-percent or 2-percent solution of a glyphosate product that contains a surfactant, or add a surfactant.
- Use 1-percent or 2-percent solution of Arsenal® AC and add a surfactant.
- Use 2-percent solution of Arsenal® and add a surfactant.
- See herbicide label for recommended surfactants.
- Use minimum sprayer pressure to control drift.
- Mix with clean water.
- Treatment is applicable to target stems less than 6 feet tall.
- Completely wet foliage.
- Apply during rain-free periods.
- Best results are obtained in late summer while foliage is still green.
- Add Oust® (sulfometuron-methyl) for better control of herbaceous weeds and grass.
- Treatment costs $150-$200 per acre (chemical and labor).

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Figure 31.—Tubed northern red oak seedlings planted on the edge of a skidroad with a heavy grass cover. A backpack sprayer was used to spray a 3-foot radius circle around the seedlings. A spray mixture containing a 2-percent solution of Glyphomate®, which contained a surfactant and the equivalent of 2 ounces of Oust® XP (sulfometuron-methyl) per acre (approximately 0.25 oz. per 3 gallons of solution), in a water carrier was used. Including Oust® XP in the spray mixture adds longevity to the treatment because Oust® XP has preemergent activity that helps prevent grass and herbaceous seeds from germinating.

James N. Kochenderfer, U.S. Forest Service (ret.)

Figure 32.—Using a backpack sprayer and minimum pressure with a 2-percent solution of Accord® Concentrate and 0.5-percent nonionic surfactant in a water carrier to spray around a seedling protected with a section of 10-inch stovepipe, equipped with a cover and handle. Foliar sprays with glyphosate herbicides are more effective later in the growing season. This same solution can also be used to prepare planting sites by spraying small circular spots of groundcover in August or September to control competition prior to spring planting.

James N. Kochenderfer, U.S. Forest Service (ret.)

Figure 33.—Foliar spraying a fern bed using a backpack sprayer and a 2-percent solution of Razor® Pro with the equivalent of 2 ounces of Oust® XP per acre in a water carrier.

James N. Kochenderfer, U.S. Forest Service (ret.)

Figure 34.—A mixture of rhododendron (*Rhododendron maximum* L.) and mountain laurel (*Kalmia latifolia* L.) that has been foliar sprayed with a 3-percent solution of Garlon® 4 and a 0.5-percent solution of Cide-Kick® II, a spray adjuvant, in a water carrier using a backpack sprayer. Use of a surfactant is very important because the waxy leaf cuticle on these plants is considered difficult to penetrate with foliar sprays. In dense thickets, using the higher labeled rate of 5-percent solution of Garlon® 4 and completely wetting the foliage but minimizing runoff are recommended.

James N. Kochenderfer, U.S. Forest Service (ret.)

Figure 35.—Direct spraying a clump of autumn olive using a backpack sprayer to thoroughly wet leaves to the point of runoff (but not causing runoff) with a 2-percent solution of Arsenal® AC plus 0.5 percent by volume nonionic surfactant in a water carrier. Nonnative invasive plants are especially difficult to control; thus follow-up treatments will probably be necessary. Since Arsenal® AC has soil activity, avoid treating areas where the roots from desirable plants are present. It is difficult to foliar spray vegetation taller than 6 feet with a backpack sprayer. Foliar spraying tall vegetation increases the possibility of drift, which can damage nontarget vegetation.

Table 4.—How to prepare various herbicide solutions for foliar spray vegetation control treatments

Desired herbicide solution concentration	Chemical name (percent active ingredient)	Herbicide component	Carrier component	Other component	All components	Reference
2-percent Glyphomate® 41 (weeds, brush, fern and grass)	Glyphosate (41.0-percent a.i.)	76 ml (3 oz.) chemical	3,709 ml (125 oz.) water	0.08 oz. Oust® XP[a]	3,785 ml or 1 gallon	Figure 31
2-percent Razor® Pro (weeds, brush, fern and grass)	Glyphosate (41.0-percent a.i.)	76 ml (3 oz.) chemical	3,709 ml (125 oz.) water	0.08 oz. Oust® XP[a]	3,785 ml or 1 gallon	Figure 33
2-percent Accord® Concentrate (weeds, brush, fern and grass)	Glyphosate (53.8-percent a.i.)	76 ml (3 oz.) chemical	3,709 ml (125 oz.) water	19 ml (0.6 oz.) surfactant	3,785 ml or 1 gallon	Figure 32
2-percent Glyphomate® 41 (weeds, brush, fern and grass)	Glyphosate (41.0-percent a.i.)	76 ml (3 oz.) chemical	3,709 ml (125 oz.) water		3,785 ml or 1 gallon	
2-percent Arsenal® AC (weeds, brush)	Imazapyr (53.1-percent a.i.)	76 ml (3 oz.) chemical	3,709 ml (125 oz.) water	19 ml (0.6 oz.) surfactant	3,785 ml or 1 gallon	Figure 35
3-percent Garlon® 4 Ultra (*Rhododendron* and *Kalmia* species)	Triclopyr (60.5-percent a.i.)	114 ml (4 oz.) chemical	3,671 ml (124 oz.) water	19 ml (0.6 oz.) Cide-Kick® II[b]	3,785 ml or 1 gallon	Figure 34
5-percent Garlon® 4 Ultra (Dense *Rhododendron* and *Kalmia* species)	Triclopyr (60.5-percent a.i.)	189 ml (7 oz.) chemical	3,596 ml (121 oz.) water	19 ml (0.6 oz) Cide-Kick® II[b]	3,785 ml or 1 gallon	Figure 34

[a]Oust® XP as sulfometuron-methyl (75-percent a.i.)
[b]Spray adjuvant

FIELD NOTES FOR FOLIAR SPRAY

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APPENDIX

Herbicide Solution Concentration Comparisons

Herbicide products are sold in a variety of concentrations of active ingredients (a.i.). For example, undiluted Glyphomate® is sold as 41.0-percent a.i. (glyphosate), while undiluted Accord® Concentrate is sold as 53.8-percent a.i (glyphosate). Use the following procedure to determine the equivalent herbicide solution mixture when changing from a familiar herbicide product and a standard solution mixture to a different herbicide product with a different concentration of active ingredient. In this example, assume you have been using a 50-percent standard mixture of Glyphomate® and you wish to change to an equivalent mixture of Accord® Concentrate.

Step 1: Assemble information about the familiar herbicide product, the desired standard solution mixture, and the mixing instructions.

Familiar herbicide product: Glyphomate® 41.0 percent-a.i. (glyphosate)
Standard solution mixture: 50 percent
Per-gallon (128 ounces) mixing instructions: Add 64 ounces (50 percent of 1 gallon) of Glyphomate® to 64 ounces of water for a total of 128 ounces or 1 gallon.

Step 2: Compute the equivalent concentration of the new or unfamiliar herbicide product and the new mixing instructions.

$$\frac{\text{Familiar herbicide}}{\text{New herbicide}} \times \text{Standard solution mixture} = \text{Equivalent concentration}$$

$$\frac{\text{Glyphomate® 41.0-percent a.i. (glyphosate)}}{\text{Accord® Concentrate 53.8-percent a.i. (glyphosate)}} \times 50 \text{ percent} = 38.1 \text{ percent}$$

A 38.1 percent solution of Accord® Concentrate is equivalent to a 50-percent solution of Glyphomate®.

Per-gallon (128 ounces) mixing instructions: Add 49 ounces (38.1 percent of 1 gallon) of Accord® Concentrate to 79 ounces of water for a total of 128 ounces or 1 gallon.

Herbicide Solution Cost Comparisons

Often there are large differences in cost for undiluted forms of herbicides. The important point to consider is the cost of the herbicide solution that will be applied for a given treatment. The following example is a comparison of stem injection solution costs ($ per gallon) for a 3-percent solution of Arsenal® AC and a 50-percent solution of Glyphomate®.

To calculate the cost per gallon for a 3-percent solution of Arsenal® AC:

Assume Arsenal® AC costs $150 per gallon.

1 gallon = 3,785 milliliters (ml)

$$\frac{\$150}{1\text{ gal}} \times \frac{1\text{ gal}}{3{,}785\text{ ml}} = \$0.0396 \text{ per ml}$$

1 gallon of a 3-percent solution of Arsenal® AC contains 114 ml (0.03 x 1 gal x $\frac{3{,}785\text{ ml}}{1\text{ gal}}$) of the herbicide.

Cost per gallon for a 3-percent solution of Arsenal® AC = $\frac{\$0.0396}{1\text{ ml}} \times 114\text{ ml} = \$4.51$ per gallon

To calculate the cost per gallon for a 50-percent solution of Glyphomate®:

Assume Glyphomate® costs $26 per gallon.

1 gallon = 3,785 ml

$$\frac{\$26}{1\text{ gal}} \times \frac{1\text{ gal}}{3{,}785\text{ ml}} = \$0.0069 \text{ per ml}$$

1 gallon of a 50-percent solution of Glyphomate® contains 1,893 ml (0.50 x 1 gal x $\frac{3{,}785\text{ ml}}{1\text{ gal}}$) of the herbicide.

Cost per gallon for a 50-percent solution of Glyphomate® = $\frac{\$0.0069}{1\text{ml}} \times 1{,}893\text{ ml} = \$13.06$ per gallon

Table 5.—Useful conversions used in forest management

Volume Conversions		
1 tablespoon (tbsp.) =	3 teaspoons (tsps.)	15 ml
1 fluid ounce (oz.) =	2 tbsp.	30 ml
1 cup =	8 oz.	237 ml
1 pint =	2 cups	473 ml
1 quart =	2 pints	946 ml
1 gallon =	4 quarts	3,785 ml
1 liter =	33.8 fl. oz.	1,000 ml or 1,000 cubic centimeters (cc)
1 gallon =	128 fl. oz.	3.785 liters
1 quart =	32 fl. oz.	0.946 liters
Weight Conversions		
1 pound (lb.) =	16 oz.	453.6 grams (g)
1 kilogram (kg.) =	2.2 lb.	1,000 g
Length Conversions		
1 inch (in.) =	2.54 cm.	25.4 millimeters (mm)
1 meter (m) =	3.28 feet (ft.)	0.001 kilometers (km)
1 mile (mi.) =	5,280 ft.	1.61 km
1 chain (ch.) =	66 ft.	20.1 m
Area Conversions		
1 acre (ac.) =	43,560 square feet	10 square chains
1 hectare (ha.) =	2.471 ac.	10,000 square meters
1 square mile (mi^2) =	640 ac.	2.59 square kilometers (km^2)

Table 6.—Summary of herbicide information

Herbicide	EPA Reg. No.	Active ingredient (%)	Herbicide cost[c] ($)	Treatment	Soil activity	Carrier	Solution conc. (%)
Accord® Concentrate (glyphosate)[a]	62719-324	53.8	$23/gal.	Foliar[d] spray, stem injection, cut-stump	No	Water	2-100
Razor® Pro[b] (glyphosate)	228-366	41.0	$17/gal.	Foliar spray, stem injection, cut-stump	No	Water	2-100
Roundup Pro®[b] (glyphosate)	524-475	41.0	$50/gal.	Foliar spray, stem injection, cut-stump	No	Water	2-100
Glyphomate® 41[b] (glyphosate)	2217-847	41.0	$26/gal.	Foliar spray, stem injection, cut-stump	No	Water	2-100
Garlon® 3A (triclopyr)	62719-37	44.4	$72/gal.	Stem injection, cut-stump	No	Water	50-100
Garlon® 4 Ultra (triclopyr)	62719-527	60.5	$91/gal.	Foliar and basal spray	No	Water-Oil	3-20
Arsenal® (imazapyr)	241-346	28.7	$119/gal.	Foliar[d] spray, stem injection, cut-stump	Yes	Water	2-6
Arsenal® AC (imazapyr)	241-299	53.1	$150/gal.	Foliar[d] spray, stem injection, cut-stump	Yes	Water	1-3
Oust® XP (Sulfometuron-methyl)	352-601	75.0	$83/lb.	Foliar	Yes	Water	2-5 oz./ac.

[a] Trade name and (common active-ingredient name)
[b] Contains surfactant
[c] Average costs obtained from herbicide distributors in 2010
[d] Requires noninonic surfactant

Labels can be downloaded at http://www.cdms.net
PLEASE READ AND FOLLOW THE LABEL.

Kochenderfer, Jeffrey D.; Kochenderfer, James N.; Miller, Gary W. 2012. **Manual herbicide application methods for managing vegetation in Appalachian hardwood forests.** Gen. Tech. Rep. NRS 96. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 59 p.

Four manual herbicide application methods are described for use in Appalachian hardwood forests. Stem injection, basal spray, cut-stump, and foliar spray techniques can be used to control interfering vegetation and promote the development of desirable reproduction and valuable crop trees in hardwood forests. Guidelines are presented to help the user select the appropriate technique and herbicide for various forest management goals. Instructions for preparing appropriate herbicide concentrations are also provided. Photos illustrate the various application methods and the tools needed to apply herbicides safely and effectively, depending on the target plants to be controlled.

KEY WORDS: herbicides, Appalachian hardwoods, stem injection, basal spray, cut-stump treatment, foliar spray, silviculture

Stem injection

Foliar spray

Basal spray

Cut-stump treatment