Tool 4: Invasive Plant Treatment Methods

Contents

This document includes original text, photos, and modifications from the source listed below. We are very thankful to the authors for allowing us to adapt this material:

Miller, James H.; Manning, Steven T.; Enloe, Stephen F. 2010. A management guide for invasive plants in southern forests. Gen. Tech. Rep. SRS–131. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 120 p. http://www.treesearch.fs.fed.us/pubs/36915

Disclaimer:

Landowner and forestry professionals should employ Integrated Vegetation Management (IVM) and consider all treatment options for prevention and treatment of terrestrial invasive plants. This tool is designed to provide a summary of what treatment methods are currently available for treatment of terrestrial invasive plants in the forested landscape in Vermont. It is not designed to weigh one method of treatment against another, nor provide suggestions to which treatment methods should be employed. Be aware that each plant species will respond differently to the treatment methods listed in this document and you should educate yourself by talking to professionals, taking workshops, and reading herbicide labels.
Go to www.vtinvasives.org for more species-specific information.

Manual Treatment Methods

Manual methods include hand pulling as well as use of a wide array of tools for cutting, pulling, and girdling invasive plants. Manual methods are mostly used on woody invasive plants when they are small, but can be used for herbaceous plants as well. Eradication is only possible when the root crown or roots that can sprout are completely extracted and seedlings are pulled or eliminated following seed germination. Because it is difficult and even impossible to extract all of the shallow roots, stolons, and rhizomes of many invasives, resprouting will usually occur. Merely pulling small plants and cutting top growth will result only in short-term control before stump or root sprouting occurs, unless an herbicide is applied to cut surfaces. If you do not plan to use herbicide, make sure to go back every spring to clip any new growth.

When using manual methods, wear gloves, a long-sleeved shirt, long pants, and eye protection. Several invasive plants can cause skin irritation, especially among sensitive individuals. Some invasive species have thorns and sharp branches that are eye hazards, as well as flying soil from wrenching and digging that might enter the eye and warrant wearing safety glasses.

Hand Pulling

This method involves pulling the invasive plant (including the underground root portions) completely out of the ground. It can be readily performed on seedlings of invasive woody plants (and some large herbaceous invasives) when soils are moist or loose. If the roots are completely extracted, then eradication is possible. But hand pulling will disturb the soil, creating a seedbed for other surrounding invasive plants that might be establishing in the site. This problem can be reduced by firming the soil with your boots, covering the area with leaf litter, and replanting dislodged desirable plants.

Digging

In some cases, the use of a shovel or other landscaping tool may be necessary to completely remove the roots. Be careful, as this method can sever the roots and cause a significant amount of soil disturbance.

Figure 1. A shrub wrench. Photo courtesy of The Nature Conservancy.

Weed Wrenching/Popping

This method uses a lever attached to a stem gripping device and a foot for extraction of woody root crowns. Shrub wrenches rely on operator weight or strength to uproot nonnative plants. These extraction tools are best suited for plants with shallow root systems, such as bush honeysuckle and other plants less than 3 inches in groundline diameter. Some brand names include the Weed Wrench™, Honeysuckle Popper, Root Talon, and Extractigator™. Shrub wrenches vary by weight, the pulling power, the size of plant that they can handle, and their foot size. Weight is a prime consideration for packing into remote locations. Pulling power of shrub wrenches currently available on the market range from 6:1 to 24:1. As an illustration of this ratio, an operator who applies 10 pounds of leverage force to the lever handle of a shrub wrench with a 12:1 pulling power ratio exerts 120 pounds of uprooting force to the plant. Foot size determines the kinds of soils the shrub wrench can be used in. Root extraction with a shrub wrench is easiest in soft soil, but working in soft soil also might hinder leverage with certain

models because of the foot size and sinking into the soil. Soil disturbance and subsequent erosion can occur on steep slopes when wrenches are used.

Cutting

Several different tools can be used to cut invasive plants:

Hand clippers

Hand clippers are useful for cutting back climbing vines and small multi-stemmed woody plants up to 1 inch in diameter. Cut as closely to the ground as possible. For vines, remove a 4- to 5-foot section to prevent regrowth trellising to the upper dead vine. Immediately apply an appropriate herbicide to the surface of the cut stem. When this is not an option, you will need to cut when resprouts appear, and do so repeatedly until no more regrowth. For most invasive vines with large roots, it is nearly impossible to deplete root energy reserves with repeated cutting. The most effective time for cutting is late spring when root reserves are lowest following spring emergence and growth. Purchase good quality clippers that have a bright color for easy locating and a holster for quick access. Always keep cutting tools sharpened, and carry sharpening stones and files to the field. Clean and maintain tools to prevent rust and provide safe operations.

Figure 2. A brush saw. Photo courtesy of Steven T. Manning.

Loppers

Loppers are long-handled shears for cutting woody stems up to several inches in diameter. Sturdy long handles, handgrips, and ratchet mechanisms can increase the stem-size cutting capability. Cuts should be positioned as close to the ground as possible to effectively remove most stem buds. Loppers are commonly used in combination with an herbicide spray bottle for treating the cut-stump to prevent re-sprouting.

Machetes, bush axes, and cane knives

Machetes, brush axes, and cane knives are useful tools for both gaining access in thick brush as well as cutting plants for herbicide stem injection and cut-treat. Solid, easy-to-grip handles, hand guards, and easy to sharpen blades are best.

Figure 3. Ringer tree girdler. Photo courtesy of Steven T. Manning.

Chainsaws

A chainsaw with a 12- to 14-inch bar is best for felling most woody invasive plants since they are light weight and suited for cutting multiple stems in clumps. Professional tree saws are usually the lightest on the market and the tool of choice among contractors.

Brush Saws

Brush Saws are large gasoline-powered weed eaters with a circular saw blade for cutting woody stems. While many large and expensive brush clearing saws are on the market, the high-end professional model is the preference of contractors for large projects. Special chainsaw-like tooth blades around a disc are the most efficient for cutting invasive plants and can be sharpened in the field throughout the life of the blade.

Girdling

Girdling is a technique that cuts through the outer bark to completely sever the phloem and cuts into the cambium. After the cut is made, the bark is removed to stop flow of sap and nutrients in the stem. The cut typically extends completely around the trunk and is between 1-5" in width at a height of 5-50" above the ground on the trunk. This method is often used for larger, woody stemmed invasive plants such as buckthorn. Both mechanical and gas-powered girdling tools are available specifically for girdling trees. Other girdling tools include chainsaws, axes, and levered chains. Most often an herbicide is added to the cut area immediately after cutting to stop stem and root re-sprouting. Girdling may result in additional hazards as subsequent dead standing trees decay and fall over time; therefore, girdling is not recommended in high-use areas (along trails or around structures).

Mechanical Treatment Methods

In many situations, hand labor is unavailable or cost prohibitive and more horsepower is needed. Developed for forestry and land clearing operations, mechanical methods use machines to clear large or dense infestations. Skid-steer loaders, tractors, bulldozers and excavators have special attachments that have been used to reduce invasive woody plants.

Land clearing methods have also been used in large treatment projects when infestations are extensive and dense. They can be followed by herbicide applications on sprouts and seedlings. Most important is using the appropriate size equipment to meet job requirements and minimize damage to soils and streams.

Timely follow-up with other control methods is essential, because soil disturbance creates favorable conditions for regrowth from seeds and root fragments. Mechanical removal with larger equipment may not be appropriate in certain natural areas. This will depend upon the sensitivity of the site and habitat and restoration plan requirements.

All mechanical equipment used in treating invasive plant infestation can transport seeds, roots, rhizomes, and spores to other sites. Equipment inspection and cleaning is essential to stop subsequent invasive plant spread.

Skid-Steer Loaders

These machines are smaller than many other land clearing machines, but are commonly used in forest management practices. Skid loaders are easily transported, highly maneuverable, and capable of lift and tilt, which gives this machine, if equipped with appropriate attachments, potential for invasive plant removal tasks in dense infestations. Tracks attached to the tires of the loader help with traction and allow access to difficult terrain. A front end mower attachment would be used to cut invasive plants. An herbicide application following mowing can be used to treat the re-sprouts. Skid-steer loaders can also use a fork attachment used to pull plants out of the ground.

Four-Wheel Drive Tractors

Forestry professionals have used specially equipped four wheel drive tractors to apply an array of vegetation management treatments. The advantages of a tractor (over heavier machinery) include good traction for pulling implements in steep terrain and moderately wet soils, versatility of power takeoff (rear power shaft) to drive implements, convenient transportability, and low operation costs. A tractor must have a substantial cab guard to prevent penetration of stray tree limbs into the operator's cab area and keep the operator safe in the event of rollover and other accidents.

Depending on its size and configuration, a tractor can use a wide range of implements to treat vegetation. Most commonly, a tractor can pull mowers that will reduce the height of herbaceous and woody invasive plants, prevent seed production, open up access for herbicide applicators, and otherwise prepare sites for further treatment. Buckets on tractors can also be used to pull plants out of the ground.

Bulldozers

Bulldozers (or tracked tractors) are made in a range of sizes, and the larger ones have played roles in forestry operations for decades. Highly developed bulldozer attachments equip them for residual tree sheering and piling after timber harvest, soil preparation, tree planting, and fire line plowing. These same operations have been used in large-scale invasive plant reclamation projects tackling extensive woody infestation, although smaller tractors and implements can also be used.

The amount of soil disturbance and compaction is considerable with bulldozers, varying by equipment size, soil moisture, number of passes, stand density, and tree/shrub size, but often less than with wheeled tractors. The ground pressure of tracks is less than with wheeled equipment.

Figure 4. A brontosaurus cutting a thick infestation of invasive plants. Photo courtesy of Chris Polatin.

Attachments for bulldozers are described below:

- **Brush rakes and root rakes** are blades with extending lower teeth that dislodge surface roots and stumps of smaller trees. Brush rakes have been used in restoration to clear dense large privet stands in preparation for other treatments before native tree and grass planting.
- **Sheer blades** are usually mounted at an angle to forward travel with a lower jutting serrated dozer blade that fells trees when pushed against them.
- **Grubbers** are sharp, U-shaped blades mounted on the front of crawler tractors, wheel loaders, excavators, or farm tractors to uproot individual trees or large shrubs. Other units clamp onto the tree and pull the tree from the soil. The size and type of tractor depends on the size of trees to be grubbed and the terrain. Units are commercially available, but many are fabricated in welding shops. Farm tractors with small, three-point hitch grubbers are popular for use on limited acreages of previously cleared areas. Grubbing is not practical in rocky soil or when tree densities are greater than 250 per acre over extensive acreages. With care, selectivity is afforded with this method, while soil disturbance is great.

Brontosaurus, Whole Tree Harvesters and Chipping
A Brontosaurus is a cutting head that is typically attached to the arm of an excavator. The cutting head is a spinning drum that cuts and grinds small diameter trees, shrubs, and limbs using centrifugal force to cut the material.

A whole tree harvesters, or feller-buncher, is an excavator that uses a large, spinning cutting blade that cuts and collects trees. This piece of equipment has become very common in many forest management projects and can be used simultaneously to cut invasive plants growing in the understory, such as large buckthorn trees. In some cases, invasives that are cut during this process can be skidded and chipped along with other trees that are being harvested during this process.

These types of excavators can range in size. Both of these pieces of equipment can be used to target vegetation in the understory, such as a dense infestation of invasive plants. In addition, movement of these pieces of equipment in the forest will effectively cut and grind woody stemmed plants, causing them to re-sprout the following year. An herbicide application can be used to treat the re-sprouts following the use of this mechanized equipment.

Herbicide Treatment Methods

Many non-native invasive plants have extensive roots, tubers, or rhizomes. This means that herbicide applications can offer effective means of containment or eradication, because herbicides can kill roots without baring soil—bared soil is susceptible to reinvasion and erosion. For successful herbicide treatments:

- Use the herbicide most effective for the targeted species and appropriate for safety to non-target species and situation.
- Follow, in detail, the application methods prescribed on the label. Adhere to all label prohibitions, precautions, and safety requirements during herbicide transport, storage, mixing, and application.
- Choose the optimum time for applications. For foliar-applied herbicides to non-evergreen woody plants, the best time is usually midsummer to early fall and not later than a month

before expected frost. Optimum application times for many herbicides on invasive plants have not been fully researched and future findings should greatly assist prescriptions.

- Be patient. After application, herbicidal activity—detectable as yellowing of foliage or as leaves with dead spots or margins—may take a month or longer. Allow herbicides to work for several months to a year before resorting to other treatment options. Consult the herbicide label for timing of expected response of treated vegetation. But when green foliage reappears, retreatments should follow.

For more information about any of the following information, **contact the Vermont Agency of Agriculture, Agricultural Resource Management division at (802) 828-2431.**

Selecting an Effective Herbicide

Each sate has a different method of classifying and approving herbicides that can legally be used in the state. To learn about registration and classification of herbicides in Vermont, go to www.vermontagriculture.com and navigate to the pesticide section.

Herbicides are identified by trade name and active ingredient name. Many active ingredients are now sold as generic herbicides at lower costs, while customer service and product liability may be different than the brand name products listed here. Because nonnative invasive plants are usually difficult to treat, selecting the most effective and appropriate herbicide(s) is important.

Often herbicides that have both soil and foliar activity are most effective with the least number of applications. However, applying herbicides with soil activity can damage desirable plants when their roots are present in the treatment zone or when herbicides move downslope to untreated areas following heavy rainfall. Some herbicides can volatilize or vaporize at high temperatures, and their residues can move by air currents to affect surrounding plants; therefore, avoid application of these herbicides on days when temperatures exceed 80 °F. Avoid applications when rainfall is anticipated, unless soil activation is needed or the label says otherwise. Consult the label for the rain fast period. Delay applications during severe drought because herbicides are not as effective when plants go into stress dormancy during dry periods.

When possible, use selective herbicides that target specific non-native species. Minimizing damage to desirable plants also can be achieved by making applications when they are dormant. Remember that desirable woody plants can be damaged through transfer of herbicides by root exudates following stem injection and cut-treat treatments or when soil-active herbicides wash off treated stems. Damage to surrounding native plants can be minimized with care and forethought during planning and application.

Organic Herbicides

Currently, very few organic herbicides exist on the market that are used for treating invasive plants in a forested setting in Vermont. In neighboring states, such as Massachusetts, some researches have begun to explore these products and they may become more common in Vermont in the near future. Research by Randy Prostak at the University of Massachusetts indicates that the organic herbicides used in his study will *not* successfully kill the plant root or rhizome and thus have to be applied regularly. He also suggests that even though these products are “organic” they are highly concentrated and can be just as dangerous to the applicator as chemical herbicide. For information about organic herbicide use in Massachusetts see:

http://www.mhd.state.ma.us/downloads/manuals/rpt_herbicides_alternative.pdf
The Northeast Organic Farming Association (NOFA) may be able to provide more information about the use of organic herbicides in Vermont in a forested setting. For more information see: http://nofavt.org/

Adjuvants and Additives to Herbicide Spray Solutions
Adjuvants are any product other than water added to a spray solution to improve herbicide performance and effectiveness, including delivery, retention on foliage, and foliar or bark penetration. Adjuvants may be included as part of the commercial herbicide product or sold separately as an additive you must mix with the herbicide before application.

Choose an adjuvant according to label recommendations and appropriate for your particular application method and field conditions. Be aware that many adjuvants are sold under invalid claims and unproven results. Before purchasing an adjuvant, ask for recommendations from reliable, certified distributors, applicators, or extension specialists. Useful adjuvants and additives include the following and are classified here according to their type of action:

Marking dyes and colorants
Marking dyes and colorants are common additive used by professionals. These additives are typically used in selective or broadcast herbicide applications, and verify that the treatment was applied to the intended target. Application dyes show how well target vegetation has been covered and whether harmful contact has been made with non-target vegetation or with the applicator. Although dyes are messy and short-lived as visible markers, they are helpful in training applicators and checking the quality of applications. Common dyes include Bullseye® Blue Spray Pattern Indicator, Hi-Light® Blue Indicator, and Blazon® Blue Spray Pattern Indicator. Bullseye is a water-soluble polymeric colorant, not a dye, and nonstaining on skin, clothing, and equipment. Bas-Oil® Red is oil-soluble and used with basal oil mixes.

Surface active agents (better known by the acronym surfactants)
Surfactants are a broad group of materials that facilitate the emulsifying, dispersing, spreading, wetting, and other surface modifying properties of liquids. Surfactants increase herbicide activity by making droplets larger on the leaf, thus improving penetration of the plant. Herbicide, weed species, and environmental conditions affect surfactant performance. Surfactants should be used with most foliar applications, except when prohibited by the herbicide label for specific uses, such as safety to desirable seeds and seedlings. Nonionic surfactants are usually recommended because they enhance wetting and retention of spray drops and do not bind with the herbicide molecule to cause deactivation. Never use household detergents as surfactants because they can deactivate many herbicides.

Water conditioners
Water conditioners are spray solution additives that enhance herbicide performance by preventing deactivation of the herbicide's active ingredient. Ammoniated salts are added to prevent loss of herbicidal activity of glyphosate and picloram when using "hard water" with greater than 200 parts per million of calcium, magnesium, and potassium. Acidifiers and buffers are additives sometimes listed on herbicide labels for use with specific water sources. Ammoniated salts, buffers, and surfactants are now blended to combine their activities in special spray additives. Because dirt and organic debris can cause herbicide deactivation, always mix herbicides only with clean water from a filtered and treated source.

Vegetable oils
Vegetable oils, such as methylated seed oil (MSO), can increase spray drop adherence to leaves, increase herbicide penetration of leaves, and slow evaporation during and after application. Herbicides must remain in solution on a leaf for plant uptake. Vegetable oils also are mixed in basal sprays, and some vegetable oils contain emulsifying agents for this purpose. Several new formulations of herbicides come with vegetable oils.

Drift retardants
Drift retardants thicken spray solutions to create larger drops that are less likely to drift in wind, permitting more accurate applications in light wind and continued applications in slightly windier conditions.

Penetrants
Penetrants partially dissolve waxy plant surfaces to help the herbicide penetrate leaves or move through bark.

Defoamers
Defoamers dissolve foam in spray tanks to improve mixing and transfers of herbicides.

Mixing Herbicides
Always use clean water in herbicide spray solutions. Thoroughly mix all ingredients before applications. Unevenly mixed herbicide solutions will produce uneven results. For large batch mixing of 5 to 200 gallons, the mixing or application tank must have an agitation system and must be operated for a sufficient time to produce a uniform mix. Mix individual batches with a stirrer in a bucket. For large batches, fill backpack sprayers from a mixing tank that has an agitation system. Fill the mixing bucket or mixing tank one-half to three quarters full with clean water. Add herbicides at label-recommended rates, with carefully calculated and measured amounts of ingredients, stirring or agitating the mixture as you add these.

Follow the herbicide label to determine how to mix herbicide, additives and adjuvants in the correct order. Over time, dry flowables and other herbicides, along with oil additives, can settle to the bottom of a tank and must be periodically agitated as specified on the label.

Backpack Sprayers
Backpack sprayers vary greatly in design and capabilities, and many versions are available commercially. The most desirable components of a backpack sprayer are a streamlined shape (to make it easy for the applicator to move through dense vegetation), an impact-resistant tank equipped with a large opening (for filling), and a solid screen (to trap debris). All backpack sprayers and spray guns should have chemical-resistant seals. Some seals are made of very durable materials and allow handling of both oil- and water-based mixtures. Backpacks with internal pressure regulators can help the applicator ensure uniform rates of application and minimize drift that otherwise might result from using too much pressure. Some models feature kink-resistant hoses for improved safety and reliability. Comfort and support in the design of a backpack sprayer cannot be overstated. Padded shoulder straps with harnesses that attach securely to the frame can reduce operator fatigue and accidents, especially in dense vegetation or on uneven terrain. Backpack sprayers come with a piston or diaphragm pump.

Piston pumps must have a regulator because they generate higher pressures. An added pressure gauge on the wand handle can help the applicator maintain a spray pressure appropriate for the given treatment. Another useful addition to a backpack sprayer is a more durable metal spray wand with a more precise shutoff valve than the valve on a flexible plastic wand. Quality backpack sprayers, which are preferred by commercial applicators, usually come with a 1- to 3-year warranty.

Spray Nozzles

Choosing the best nozzle will usually require that you purchase another nozzle and not use the one that comes with your sprayer. Correct nozzles can greatly improve effectiveness and efficiency. Nozzles consist of a nozzle body, a cap, and a tip with the orifice. The spray tip is the most important part of your sprayer because it breaks the liquid into droplets of the correct size and forms the spray pattern.

Tips are made of a variety of materials. Most readily available tips are made of plastic, brass, and stainless steel. Tips of harder materials initially may cost more but will pay for themselves in the long run with durability and consistent performance. Plastic tips tend to have very irregular spray patterns. Brass tips can be easily damaged during cleaning, and such damage will cause irregular spray patterns. It is a good practice to discard plastic or brass nozzles that come standard with a sprayer and replace them with tips of stainless steel designed for long-term commercial use.

Stainless steel tips provide a uniform and consistent spray pattern over longer periods and are known for having fewer out-of-the-box defects. Air induction tips are newer modifications. These tips produce large, air-filled drops that help reduce the potential for drift in winds. They work by drawing air through two holes in the nozzle sides, which blends the air with the herbicide mix. They emit a spray of large droplets filled with air bubbles and virtually no drift-prone droplets. Other nozzle alternatives include “low-drift” and “extended-range” tips that produce fewer small stray droplets and aerosols that contribute to drift compared to conventional nozzles. When choosing air induction or stainless steel nozzles, consider models with a plastic body and a steel tip, because these models are as durable as more expensive all-steel nozzles. Low-volume directed sprays are often applied with a backpack sprayer and a spray wand equipped with a full cone, flat-fan, or adjustable cone spray tip. The tip has the orifice, which is usually identified by a four-digit number representing its spray pattern angle and flow-volume specifications; for example, an 8002 tip has a spray pattern angle of 80 degrees and a flow volume of 0.2 gallons per minute (all flow volumes are measured at 40 pounds per square inch of pressure). When your application is for invasive plants, models SS4004E (SS = stainless steel, E= even pattern); SS8004E; SS2504; and a wide-angle flooding nozzle like the Floodjet TK VS3 yield good coverage, useful flow rates, and are good additions to your toolkit. A range of tips should be carried to the field so that the best nozzle for plant heights, terrain, and weather can be selected. To purchase nozzles and spray components and parts, consult an agricultural products outlet, farm tractor dealer, or farm store.

Sprayer Preparation

Prior to calibration of equipment and application of herbicides, applicators must properly prepare their equipment. Thoroughly clean all nozzles, screens, and filters in detergent solution, using a soft bristle brush, and then rinse. Make certain that all nozzles are the same size, prescribed for the application, and made of the same material for uniformity by all applicators and especially when several nozzles are along a short boom. Replace nozzles that do not have uniform spray patterns (often determined by spraying along a concrete surface). Check flow rates periodically by catching spray in a container over a timed period. Stay alert for dripping nozzles and use check values to prevent drips. Select an operating

pressure consistent with the desired gallons per acre output and spray pattern relative to wind conditions.
Check all personal protective equipment (PPE), replace faulty items, and make certain that all applicators are trained in use and maintenance of all items. Always use the appropriate PPE for each operation, and perform daily maintenance on this equipment.

Backpack Sprayer Calibration
Prescriptions for invasive plant applications are often given as percent-solutions of specific herbicides. But on herbicide labels, most prescriptions are given in herbicide volume or weight (dry herbicides) per acre. This requires calibration of a spray system using the same nozzle(s) and pressure that will be used during application. Calibration is simply the determination of how much spray volume is applied to a specified area of land. Calibration requires timing an application to a known area, which is then expressed as gallons per acre. This should be done in the treatment area because factoring in the speed of the applicator who works in those conditions is crucial for accurate calibration. Water alone should be used for calibration procedure.

For calibrating broadcast sprays, measure the width of the spray swath in feet and multiply this measurement by the distance traveled in feet for 1 minute. Convert this result to an acre basis by dividing the square feet by 43,560 square feet per acre. Catch the spray from the nozzle(s) for 1 minute and measure the volume in ounces. Convert this measurement to gallons by dividing by 128 ounces per gallon. Gallons per acre then can be calculated by dividing the measured gallons by the part of an acre treated. The calculated "gallons per acre" output during application will be a mixture of herbicide, water, and any additional adjuvants. The amount of herbicide prescribed per acre is specified on the label; this is the amount you should mix with the "gallons per acre" determined during calibration. For example, if a prescription calls for 2 gallons of herbicide per acre, and if your sprayer is calibrated to apply 20 gallons per acre, then, to treat 1 acre, you must mix 2 gallons of herbicide in 18 gallons of water and adjuvants. For mixing an individual batch for a 4-gallon backpack sprayer, you would divide these quantities by 5. If you need to apply more or less gallons per acre as specified on the label or dictated by vegetation conditions, the nozzle size(s) and/or pressure should be changed. Higher pressures or larger tips will increase output, while increasing pressure may increase drift potential.

You can use the same calculation methods for foliar-directed sprays and for sprayers mounted on tractors and other equipment. For foliar sprays, you will treat individual plants in the measured area (some part of an acre) and then you can refill your sprayer according to a marked pre-application level to determine the gallons applied. For calculations of mounted sprayers, you will need to consider a large calibration area and capture spray from all nozzles, both over a timed period as before.

Foliar Spraying and Wiping
Directed foliar sprays are herbicide-water-adjuvant solutions aimed at target plant foliage to wet all leaves.

Herbicide application by directed foliar spray is one of the most cost-effective methods for treating many types of herbaceous and woody invasive plant species. With this method, herbicide mixtures are applied to the foliage and especially the growing tips of woody plants, or to completely cover herbaceous plants. Foliar sprays can be applied whenever leaves are present but, for woody plant control, are usually most effective from midsummer to late fall.

prayers. Photo

pplication of
of Courtney Haynes.

Selective treatment is possible because the applicator can direct the spray towards target plants and away from desirable plants. The addition of a spray shield to the end of the wand confines spray to the target. Another safeguard is to only use foliar-active herbicides, because directed sprays of soil-active herbicides can damage or kill surrounding plants when their roots are within the treatment zone. Never use herbicides with soil activity to treat invasive plants under desirable trees or shrubs that are susceptible to the herbicide. If non-target foliage is accidently sprayed, clip off the foliage to prevent uptake. Low-volume foliar sprays using spray tips and spraying pressures of 20 to 30 pounds per square inch can ensure productivity and limit drift to surrounding plants. Plants up to 6 feet tall can be treated with this equipment, while the addition of a commercially available wand extension can slightly increase height capabilities. Wind must be minimal (less than 2 miles per hour) and used by the applicator to facilitate upper crown coverage. A handgun with a rollover valve can replace the spray wand and accommodates two tips, such as a flat fan for close spraying and a narrow flat fan or adjustable cone nozzle for tall plant spraying. This setup greatly extends applicator capabilities and productivity when invasive infestations vary in height. Sturdy metal wands can replace plastic ones for more precise applications.

rt application system and
. Photo courtesy of Steven

Handheld weed wicks and rollers apply ultra-low volumes by wiping the herbicide mix onto the target leaf surfaces or bark; the herbicide mixture is contained in the handle. A few commercial models are manufactured, but devices also can be handmade from PVC tubing, fittings, and a sealed on sponge or rope wick and fitted to the wand of a backpack sprayer. Most wick systems have limited use and durability in forest and field situations, but are useful when the applicator needs to avoid applying herbicide to rare or protected plants. Similar to a weed wick applicator, a rolling sponge head is another drift-free tool option that allows application directly to targeted species.

The THINVERT ® Application System uses a series of special spray nozzles to apply thin invert emulsion spray solutions (thin milkshake like consistency) to greatly reduce drift and evaporation of spray particles on the plant surface. The nozzles and a combination of special oil soluble herbicide and emulsifying agent have been developed and sold by Arborchem Products Company (717–766–6661, www.arborchem.com). This system combines the unique spray nozzle and spray carrier into a coordinated unit for aerial or ground applications to roadsides, rangeland, cropland, industrial sites, forests, and landscape areas. Thinvert sprays can be applied to foliage as well as stems or cut-stumps where absolutely no drift can be tolerated, such as immediately adjacent to neighboring croplands and special rare plant habitats.

Backpack Mist Blowers

Broadcast applications can be made with a gasoline powered backpack mist blower. A wind turbine creates fine droplets that penetrate into shrubby stands and onto the foliage, but these droplets readily drift with wind and fog. As a safeguard to nontarget plants, foliar-active herbicides are usually recommended. These applications are only suitable for internal lands with dense infestations where drift of the mist-spray drops will be intercepted by target foliage and not move to nontarget plants or lands. Wind is critical for controlling this application. Wind must be minimal and moving away from a lane or spot of application into the target foliage.

Figure 9. A mist blower backpack sprayer. Photo courtesy of Courtney Haynes.

Applications must cease when gusts begin to occur. *Be cautious with this method when using in a forested setting, since broadcast application (see definition below) is illegal*. See language from the Moratorium on Aerial or Broadcast Application of Herbicides 1997, No. 30 *§ 1: "A moratorium is imposed on the aerial or other broadcast application of herbicides as herbicides are defined in section 911 of Title 6, for forestry purposes. As used in this section, 'the application of herbicides for forestry purposes' is limited to the use of herbicides in the commercial production of hardwoods and softwoods and does not include the use of herbicides in the production of agricultural products as defined in 6 V.S.A. § 2964(e), or the use of herbicides to preserve utility rights-of-way. For purposes of this section,* ***broadcast application*** *is defined as general application to an area other than by on-foot application to specific target plants using any of the following application methods:*

backpack mist sprayer, tree injector, handheld spray bottle, wick, or brush."

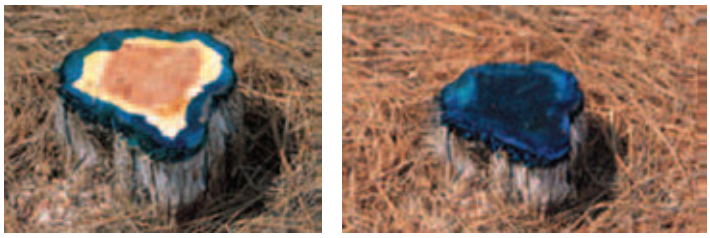

Figure 8. Stumps showing herbicide application (indicated by blue dye) around edge of cut stump and entire cut surface. Photos courtesy of Steven T. Manning.

Cut Stump/ Cut Surface

Cut Stump involves applying herbicide concentrates, herbicide-water or herbicide-penetrant mixtures to the outer circumference of freshly cut stumps or the entire top surface of cut stems. Applications of herbicide are made with a spray or squirt bottle, backpack sprayer, wick, or paint brush and should be done immediately following cutting.

Cut surface involved applying herbicide concentrates, herbicides-water or herbicide-penetrant mixtures to the entire surface of the cut surface. Applications of herbicide are made with a spray or squirt bottle, backpack sprayer, wick or brush and should be done before one month of cutting the surface.

Freshly cut stems and stumps of trees, woody vines, and shrubs can be treated with herbicide mixtures to prevent re-sprouting and to kill roots. It is critical that the cut is made as low as possible to the ground, and that the stem is treated appropriately after the cut is made. Invasives not treated with herbicides after cutting invariably re-sprout and intensify their infestation. Cutting is usually by chainsaw or brush saw but can be made by handsaws and cutting blades.

Figure 10. A chain saw and hand-held squirt bottles are the most common tools used for the cut stump/surface application method. Photos courtesy of Steven T. Manning and Courtney Haynes.

To minimize deactivation of the herbicide in the cut stump method, remove sawdust from stumps before treatment. For stumps over 3 inches in diameter completely wet the outer edge with the herbicide or herbicide mixture. Make certain that the solution thoroughly covers the wood next to the bark of the stump. Completely wet the tops of smaller stumps and all cut stems in a clump. Apply a basal spray mixture of herbicide, oil, and penetrant to stumps that have gone untreated for over 2 hours. Make certain to wet stump sides and root collar to further prevent sprouting.

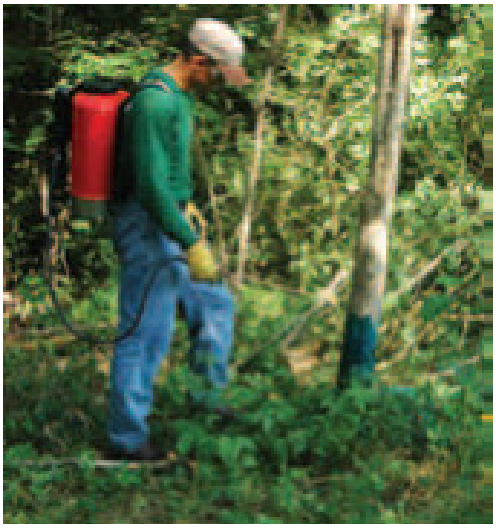

Figure 11. Basal bark herbicide application (indicated by blue dye). Photo courtesy of Steven T. Manning.

Basal Sprays and Wipes

Basal sprays are herbicide-oil-penetrant mixtures sprayed on the lower portion of woody shrub, vine, and tree stems. The sprays are usually applied with a backpack sprayer or wick applicator. Basal sprays are best where most trees are less than 8 inches diameter breast height (d.b.h.), but can be used on much larger trees

of susceptible species. Herbicide labels will indicate the maximum d.b.h they are effective on. Application is to smooth juvenile bark by thoroughly wetting the lower 12 to 20 inches of the trunk, up to 36 inches on larger trees to the ground line including the root-collar area and any exposed roots. Smaller trees and shrubs are controlled with less coverage. Avoid spray contact with desirable trees or heavy use within their root zone. The herbicide must be an oil-soluble formulation and mixed with a special basal oil product, penetrating oil, diesel fuel, fuel oil, mineral oil, vegetable oil with a penetrant, or blends of these ingredients. Appropriate oils will be specified on the herbicide label. Some oils may be prohibited for application in riparian areas and wetlands. Use an adjustable cone nozzle with a coarse spray. For less off-target spray on smaller trees, use an even flat-fan nozzle with a fairly narrow angle and low volume (such as a 4002E, oriented crosswise to the wand for a spray that lands in a vertical band on the stem).

After treating with a basal spray, wait at least 6 months before cutting dead trees, because herbicide activity within plant roots can continue for an extended period.

Stem Injection (aka Hack and Squirt or Frill)

Stem injection involves herbicide concentrate or herbicide water mixtures applied into downward incision cuts spaced around woody stems. Cuts are made by an ax, hatchet, machete, brush ax, cane knife, or a variety of cutting tools and even cordless drills. Tree injection is a selective method of controlling larger trees, shrubs, and vines (greater than 2 inches in d.b.h.) with minimum damage to surrounding plants. Stem injection is a fast and cost-effective method for nonnative trees and large shrubs. Injection treatments are sometimes not as effective in controlling multiple-stemmed species compared to the faster basal bark treatments, but may be easier in remote or rough terrain where a backpack sprayer might be impractical or cumbersome. Stem injection is physically demanding for the applicator, who must repeatedly and accurately strike target trees with a sharp tool before delivering the herbicide into the cut. For best results, sharpen tools frequently.

Figure 12. Hack and squirt herbicide application methods.

Incisions must be deep enough to penetrate the bark and inner bark, slightly into the wood. Do not make multiple cuts directly above or below each other because this will inhibit movement of the herbicide within the stem. A complete girdle or frill of the stem is not needed or desirable. Space the injection cuts 1 to 1.5 inches apart edge to edge (or per label instructions) around the circumference of each trunk individually or within a clump at a convenient height. Use a handheld, chemical-resistant spray bottle to apply 0.5 to 2 mL of concentrated herbicide or dilutions (prescribed on the label) into the cut. The amount will depend on the size of cut and how much the cut can hold without the herbicide running onto the bark. Apply herbicide to each cut until the exposed area is thoroughly wet. The herbicide should remain in the injection cut to avoid wasting herbicide and to prevent damage of surrounding plants. All injected herbicides can reach untreated plants by root grafts between like species, and uptake of root exudates by all species results in nontarget damage.

Herbicides with soil activity can damage nearby plants when washed from incisions into the soil by unexpected rainfall soon after application. Avoid injection treatments if rainfall is predicted within 48 hours. Prolonged cold temperatures can freeze herbicide in the cut, resulting in poor absorption. Heavy spring sapflow can wash herbicide from incision cuts, resulting in poor control and soil transfer to nontarget plants. Prolonged and severe drought is also an ineffective period.

Special tree injectors are available that combine the cutting operation with automated herbicide delivery. For injecting some herbicides (amine formulations), the Hypo- Hatchet® Tree injector (Forestry Suppliers Inc., 800–647–5368, www.forestry-suppliers. com) consists of a steel hatchet connected to a herbicide container (worn on belt) by tubing. The injector delivers a set amount of herbicide into the cut. Daily cleaning and lubrication of the impact piston is required maintenance, along with periodic replacement of rubber o-rings and seals. Check all hoses and fittings before use for leaks and make appropriate repairs to prevent accidental exposure of herbicide to the applicator. When working with the Hypo-Hatchet in dense infestations, be mindful of the supply tubing, which might become tangled and easily disconnected. Another injector is the EZ-Ject®, which consists of a steel lance that holds 400 shells of an herbicide (ArborSystems, 888–395–6732, www.ezject.com). The head of the lance is placed against the base of the target woody plant, and a manual thrust jams the shell through the bark into the inner bark. As with other injection methods, these shells are spaced around each stem. The EZ-Ject is the most efficient and effective injection option for treating multi-stemmed, low-branching shrubs like and bush honeysuckles(*Lonicera* spp.), as well as large entangled vines like oriental bittersweet (*Celastrus orbiculatus* Thunb.). Shell jamming has been reported as a problem when using the EZ-Ject to treat extensive infestations. Removing the herbicide shells when not in use, proper use, and daily maintenance can help prevent jamming.

Figure 13. Stem injector used for Japanese knotweed. Photo courtesy of Chris Polatin.

Special stem injectors have also been developed for Japanese knotweed (*Polygonum cuspidatum.* This method should be used on stems that are over ½ of an inch in diameter. For best results, cut and apply herbicide during the time of year when the plant is flowering. Be aware that this method has the potential to exceed maximum allowable amounts of herbicide if treating a large patch of Japanese knotweed.

Other Treatment Methods

Flame Weeding

Fire from a propane spot burner can be used to kill individual or small groups of invasive plants. Commercial kits are available for attaching propane cylinders to a backpack frame and fitting the cylinder with a flame nozzle. When plant and wet fuel conditions permit, the flame is directed at herbaceous and woody invasives. This operation can be convenient since it can be performed in wet conditions and when fuels are low. Best results are obtained under windless conditions as winds can prevent the heat from reaching the target weeds. For further details, refer to The Nature Conservancy's "Weed Control Methods Handbook" appendix at http://www.invasive.org/gist/products/handbook/23.Spotburn.pdf

Figure 14.Direct flame weeding. Photo courtesy of Chris Polatin.

Prescribed Grazing

Prescribed grazing is an approach that relies on cattle, sheep, goats, and horses to reduce infestations. Grazing is a potential control treatment when there is no risk of damage to native plants, the invasive is palatable and the invasive plant is not poisonous to the animal. The animal species is important as is the breed, the best being those breeds that are larger and can handle difficult grazing and browsing conditions.

Multiple years are required to achieve major invasive plant reductions and additional methods are required for restoration. The key to control is repeated heavy defoliation in spring and early summer without overgrazing grasses and legumes, thus a rotation system is likely necessary.

For more information consider: University of Idaho Rangeland Ecology and Management. Targeted Grazing: A Natural Approach to Vegetation Management and Landscape Enhancement. http://www.cnr.uidaho.edu/rx-grazing/Handbook.htm. The handbook outlines the basics of applying targeted grazing for vegetation management. This handbook includes 18 chapters and represents a compilation of the latest research on harnessing livestock to graze targeted vegetation in ways that improve the function and appearance of a wide variety of landscapes.

Biocontrol

Biological control, or biocontrol, of plants uses living organisms to weaken, kill, or stop seed production of a targeted invasive plant. The most common agents in biocontrol programs are insects and pathogens, and uses of nematodes and mites are under study.

Classical biocontrol involves finding agents in the home range or similar habitat of the invasive plant, followed by intensive research on feeding habits and reproduction, and a planned introduction of plant-specific agents into invaded areas. The goal is to identify predators that are host specific to the target invasives, i.e., they will not attack native plants, and will increase and spread in the new range to permanently suppress the invasive species. Classical biocontrol has an initially high public cost due to an often lengthy search for the right agent, extensive feeding tests in special quarantine facilities, coordinated releases, and long-term monitoring. There are specific requirements through a series of scheduled oversights by a Federal Government interagency committee requiring documented studies to strictly control biocontrol agent releases. Following release, non-target damage is very rare but can occur.

Augmentative and inundative biocontrol identifies native insects, pathogens, nematodes, and mites that feed upon nonnative invasive plants in this country. When the appropriate agents are discovered and researched, there is an attempt to release large numbers of them into high infestation areas of the invasive plant. The State of Vermont has used biocontrol methods to treat purple loosestrife (Lythrum salicaria). All biocontrol efforts are regulated and employed but the State.