Downloaded by Randy Westbrooks on September 29, 2011 | http://pubs.acs.org
Publication Date (Web): September 15, 2011 | doi: 10.1021/bk-2011-1073.ch019

Chapter 19

Chemical Control Methods and Tools

Steven Manning*,[1] and James Miller[2]

[1]Invasive Plant Control, Inc., Nashville, TN
[2]USDA Forest Service, Auburn, AL
***E-mail: steve@ipc-inc.org**

After determining the best course of action for control of an invasive plant population, it is important to understand the variety of methods available to the integrated pest management professional. A variety of methods are now widely used in managing invasive plants in natural areas, including chemical, mechanical, and cultural control methods. Once the preferred method of control is identified and the appropriate personal protective equipment has been chosen, the next step is to determine the specific types of equipment that should be used to create the most selective, efficient and affect control of the target species. Chemical control is one of the most frequently utilized tools in this industry. Proper use of chemicals is important and the applicator must always remember that the label is the law. No application offers guaranteed success, but proper use of chemicals and associated tools will increase the effectiveness of the treatment. This involves an understanding of the benefits of adjuvants, proper mixing and application protocols, and finally the correct choice and proper use of low volume, high volume or selective spray equipment.

I. Introduction

Many nonnative invasive plants are perennials, with extensive roots, tubers or rhizomes. As a result, effective chemical treatments usually offer the best means of containment or eradication. This is because herbicides can kill the roots and do so without baring the soil (which would allow for reinvasion or erosion).

© 2011 American Chemical Society
In Invasive Plant Management Issues and Challenges in the United States: 2011 Overview; Westbrooks, R., et al.; ACS Symposium Series; American Chemical Society: Washington, DC, 2011.

To be successful with herbicide treatments:

- use the most effective herbicide for the species,
- follow the application methods prescribed on the label,
- choose an optimum time period to apply treatments; for foliar-applied herbicides this is usually mid-summer to early fall and not later than a month before expected frost,
- evergreens and semi-evergreens with leaves can be treated effectively in the winter,
- adhere to all label prohibitions, precautions, and Best Management Practices during herbicide transport, storage, mixing, and application,
- remember that some herbicides require up to a month or more before herbicidal activity is detectable as yellowing of foliage or leaves with dead spots or margins. Thus, after application, be patient; allow herbicides to work for several months before resorting to other treatment options.

II. Herbicide Selection and Use

Only herbicides registered by the U.S. Environmental Protection Agency for forestry use and noncroplands in the southern states will be discussed here, although herbicides for other land use areas, such as right-of-ways, pastures, and rangelands, may be just as effective or may contain the same active ingredient.

Because nonnative invasive plants are usually difficult to control, selecting the most effective herbicide(s) is important. Often herbicides that have both soil and foliar activity are most effective with the least number of applications. However, it is important to remember that applying herbicides with soil activity can damage desirable plants when their roots are present within the treatment zone or when herbicides move downhill to untreated areas following heavy rainfall. Garlon 4® (triclopyr), Vanquish® (dicamba), and Transline® (clopyralid) are three herbicides that are widely used in forests and non-croplands in the southern states.

Garlon 4 is mainly a foliar active herbicide, but it does have some soil activity at high rates or when mixed with oils. Garlon 4 and Vanquish can volatilize or vaporize (Vanquish actually vaporizes) at high temperatures and their residues can move by air currents to affect surrounding plants. Therefore, avoid application with these herbicides on days when temperatures exceed 80° F. If possible, also avoid applications when rainfall is anticipated within eight hours, unless soil activation is needed, and during periods of severe drought as effectiveness can be reduced during these times. Consult the label for the rainfast period and drought prohibitions.

When possible, use selective herbicides that target specific non-native species, such as Transline that controls mainly legumes and composites, and minimize damage to surrounding desirable plants even though they receive herbicide contact. Minimizing damage to desirable cohorts can also be achieved by making applications when the cohorts are dormant. For example, apply basal sprays to the bark of invasives in late winter before most other plants

In Invasive Plant Management Issues and Challenges in the United States: 2011 Overview; Westbrooks, R., et al.; ACS Symposium Series; American Chemical Society: Washington, DC, 2011.

Downloaded by Randy Westbrooks on September 29, 2011 | http://pubs.acs.org
Publication Date (Web): September 15, 2011 | doi: 10.1021/bk-2011-1073.ch019

emerge, or foliar spray evergreen or semi-evergreen invasives after surrounding plants have entered dormancy. 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 (Figure 1).

Figure 1. Timing of treatments to minimize off-target impacts. Image by Steven Manning, Nashville, Tennessee.

Downloaded by Randy Westbrooks on September 29, 2011 | http://pubs.acs.org
Publication Date (Web): September 15, 2011 | doi: 10.1021/bk-2011-1073.ch019

A. Adjuvants and Additives

Adjuvants are products that are added to a spray solution to enhance or modify its performance. Adjuvants are either included in herbicide formulations as part of the total product, or are sold as an additive to be mixed with herbicide products in the spray tank. Adjuvants are classified according to their type of action. The choice of an adjuvant should be based on the specific need to complement the herbicide being applied. Another common additive used by professionals is a marking dye, which is not an adjuvant.

Marking dyes and colorants are considered necessary in selective or broadcast herbicide application to allow the applicator to verify that the herbicide application has been applied to the intended target. Dyes are an indicator of the applicator's efficiency of limiting herbicide contact with non-target vegetation and personal contact. The addition of a water-soluble dye can assist in tracking treatment and detecting spray drift on desirable plants. Although dyes are messy and short-lived as a visible marker, they are helpful in training and checking the quality of applications (Figure 2).

In Invasive Plant Management Issues and Challenges in the United States: 2011 Overview; Westbrooks, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2011.

Figure 2. Application of dyes to cut stump. Image by Steven Manning, Nashville, Tennessee.

Sticker spreaders are sticking agents designed for use with herbicides which can reduce or eliminate the need for conventional surfactants. The agent forms a sticky, elastic film which can hold the herbicide on the plant foliage and greatly reduce runoff of the spray residue. Do not mix a sticker spreader into an herbicide mix that already contains a surfactant as this will decrease the herbicides effectiveness.

Surfactants are materials that facilitate and accentuate the emulsifying, dispersing, spreading, wetting, or other surface modifying properties of liquids. Herbicide, weed species and environmental conditions affect surfactant performance. Surfactants should be used in most foliar applications, but it is important to adhere to the herbicide label recommendations.

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.

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.

B. Herbicide Mixing

Always use clean water in an herbicide mixture and mix spray solutions thoroughly before applying. Before adding an herbicide to a spray tank, mix it thoroughly in a separate mixing container (Figure 3).

In Invasive Plant Management Issues and Challenges in the United States: 2011 Overview; Westbrooks, R., et al.; ACS Symposium Series; American Chemical Society: Washington, DC, 2011.

Downloaded by Randy Westbrooks on September 29, 2011 | http://pubs.acs.org
Publication Date (Web): September 15, 2011 | doi: 10.1021/bk-2011-1073.ch019

Figure 3. Herbicide mixing. Image by Steven Manning, Nashville, Tennessee.

Downloaded by Randy Westbrooks on September 29, 2011 | http://pubs.acs.org
Publication Date (Web): September 15, 2011 | doi: 10.1021/bk-2011-1073.ch019

C. Directed Foliar Sprays

Directed foliar sprays are herbicide-water sprays aimed at target plant foliage to cover all leaves to the point of runoff, applied with various low and high volume spray equipment. Herbicide application by directed foliar spray is a cost effective method for treating many types of invasive plant species. With this method, herbicides are thoroughly mixed in water, often with a non-ionic surfactant, and applied to the foliage and growing tips of woody plants or to completely cover herbaceous plants. Foliar sprays are usually most effective when applied from midsummer to late fall, although spring and winter applications have use on specific plants and situations. Selective treatment is possible because the applicator directs the spray towards target plants and away from desirable plants. 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 (Figure 4).

Figure 4. Directed foliar spray. Image by Steven Manning, Nashville, Tennessee.

In Invasive Plant Management Issues and Challenges in the United States: 2011 Overview; Westbrooks, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2011.

D. Spray Drift

Spray drift is the movement of a pesticide through air during or after application to a non-target site (Figure 5). Several factors play a role in creation or reduction of drift including:

- Volatility and viscosity of herbicide formulation
- Applicator experience and technique
- Weather conditions at the time of application
- Equipment type and quality

Figure 5. Application of herbicides near a waterway. Image by Steven Manning, Nashville, Tennessee.

Table 1. Effect of wind speed on herbicide spray droplets

Droplet Type	Time to Fall a Distance of 10 Feet	Lateral Distance Droplets Travel in Falling 10 Feet in a 3 mph Wind
Fog	66 Minutes	3 Miles
Very fine spray	4.2 Minutes	1,100 Feet
Fine spray	10 Seconds	44 Feet
Medium	6 Seconds	28 Feet
Coarse	2 Seconds	8.5 Feet
Fine rain	1 Second	4.7 Feet

Wind speed and direction as well as spray droplet size are important factors that affect drift (Table 1). Small-to-medium size droplets are desirable when applying herbicides to achieve good coverage and foliage penetration. However, it is important to remember that smaller droplets can drift long distances because of their light weight. Newer modified nozzles increase the efficiency of small droplets while reducing the potential for drift. This is accomplished by using

In Invasive Plant Management Issues and Challenges in the United States: 2011 Overview; Westbrooks, R., et al.; ACS Symposium Series; American Chemical Society: Washington, DC, 2011.

Downloaded by Randy Westbrooks on September 29, 2011 | http://pubs.acs.org
Publication Date (Web): September 15, 2011 | doi: 10.1021/bk-2011-1073.ch019

new atomizers, air-assist technology, or shields to overcome drift-producing air currents and turbulence that occur around the nozzle during spraying.

III. Herbicide Application Equipment

A. Equipment Use and Care

In order to be effective, herbicides must be applied to a target species at the correct concentration. This is accomplished by the use of appropriate equipment that is properly prepared, calibrated, and used according to the manufacturer's specifications.

1. Sprayer Preparation

Prior to calibration of equipment and application of herbicides, applicators must properly prepare the equipment. First, thoroughly clean all nozzles, screens and filters to ensure a uniform application and make sure all nozzles are made of the same material such as stainless steel. Second, replace nozzles that do not have uniform spray patterns and select an operating pressure consistent with the desired gallons per acre output.

2. Nozzles and Equipment Calibration

Choosing sprayer nozzles is not as simple as using the nozzle that comes with your equipment. The spray tip is the most important nozzle accessory for your sprayer (Figure 6). It breaks the liquid into droplets of the correct size, forms the spray pattern, and projects the droplets. Nozzle tips are designed for various uses and spray pressures.

Figure 6. Herbicide application nozzles. Images by Steven Manning, Nashville, Tennessee.

Spray tips are made from a variety of materials. Tips made of harder materials may cost more initially, but are more durable. The most common tips available for use with backpacks are plastic, brass, stainless steel and air induction. Plastic nozzles tend to have very irregular spray patterns from manufacturer defects. Brass

In Invasive Plant Management Issues and Challenges in the United States: 2011 Overview; Westbrooks, R., et al.; ACS Symposium Series; American Chemical Society: Washington, DC, 2011.

Downloaded by Randy Westbrooks on September 29, 2011 | http://pubs.acs.org
Publication Date (Web): September 15, 2011 | doi: 10.1021/bk-2011-1073.ch019

nozzles have a tendency to be easily damaged creating irregular spray patterns. It is a good practice to discard plastic or brass nozzles after purchase and replace with stainless steel or air induction.

Newer "low-drift" nozzles can reduce the risk of creating drift and are more effective in reducing the number of small droplets than what can be accomplished using the conventional nozzles. Stainless steel nozzles have fewer out of the box defects, and are much more durable than brass or plastic. Stainless steel provides a uniform and consistent spray pattern. Air inclusion, air induction or "venturi" nozzles create negative pressure inside the nozzle body. Air is drawn into the nozzle through two holes in the nozzle side, blending with the herbicide mix. The emitted spray contains large droplets filled with air bubbles and virtually no drift-prone droplets.

The best nozzles with the least amount of factory faults are either stainless steel or air induction. Although they are more expensive in the short term, their longer wear life often results in lower long-run costs. When the primary focus is invasive plants, models 40.02E SS (Stainless Steel), 80.04E SS, 25.04 SS and Floodjet TK VS3 are good additions to your toolkit. When purchasing air induction or stainless steel nozzles, purchase models that comprise a plastic body with a steel tip. These are just as durable at a reduced price (Figure 7).

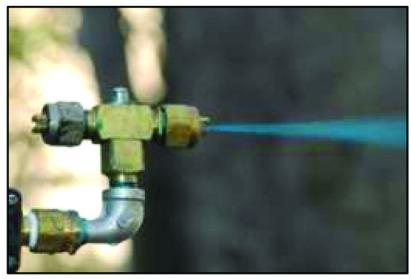

Figure 7. Spray nozzle swivel with interchangeable tips. Image by Steven Manning, Nashville, Tennessee.

3. Application Equipment Cleaning

It is important to thoroughly clean equipment at the end of every workday. It is a good principle to mix only what you will need for the day. If there is herbicide mixture left over at the end of the day, spray the remaining chemical onto the target vegetation on the site and clean the tank prior to departure. When changing from a water-based mix to an oil-based mix in a backpack sprayer, thoroughly evacuate the water from the pump and run a small amount of oil through the pumping system before filling with the oil-based mix, otherwise, a white sludge will clog the sprayer.

Downloaded by Randy Westbrooks on September 29, 2011 | http://pubs.acs.org
Publication Date (Web): September 15, 2011 | doi: 10.1021/bk-2011-1073.ch019

In Invasive Plant Management Issues and Challenges in the United States: 2011 Overview; Westbrooks, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2011.

B. Low Volume Herbicide Application Equipment

Using tips and spraying pressures of 20 - 30 pounds per square inch can ensure productivity with only a few fine droplets that may 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. To treat plants up to about 18 feet tall, use higher spray pressures with a straight-stream or narrow flat fan tip.

1. Hand Sprayers

Most hand sprayers available commercially are made for occasional weekend users (Figure 8). If you require a model that will be used in continuous daily operations consider purchasing one that is chemical resistant with mechanically robust Viton® gaskets and a manual hand pump. A good hand sprayer will also have an adjustable mist nozzle and a large filling opening for easier mixing. Models with pump compression design are good for cutting and treating, while trigger action pumps are better suited for stem injection treatments.

Figure 8. Handheld sprayers. Images by Steven Manning, Nashville, Tennessee.

2. Backpack Sprayers

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. Backpack sprayers vary greatly and many versions are available commercially (Figure 9). The most desirable components of a backpack sprayer are a streamlined shape (to make it easy for the applicator to move through dense vegetation) and 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. Viton® seals are made of the most 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 have kink resistant hoses and any model purchased should have a 1 - 3 year warranty. A spray gun with a narrow flat fan tip can replace a wand for some applications.

In Invasive Plant Management Issues and Challenges in the United States: 2011 Overview; Westbrooks, R., et al.; ACS Symposium Series; American Chemical Society: Washington, DC, 2011.

Downloaded by Randy Westbrooks on September 29, 2011 | http://pubs.acs.org
Publication Date (Web): September 15, 2011 | doi: 10.1021/bk-2011-1073.ch019

Figure 9. Backpack sprayers. Image by Steven Manning, Nashville, Tennessee.

Downloaded by Randy Westbrooks on September 29, 2011 | http://pubs.acs.org
Publication Date (Web): September 15, 2011 | doi: 10.1021/bk-2011-1073.ch019

3. Weed Wick Applicators

Weed Wick Applicators consist of a wick or rope soaked in herbicide from a reservoir attached to a manual use handle or electrical pump equipment. The wetted wick is used to wipe or brush herbicide over weeds as it passes over them. Three types of wick applicators have been traditionally used in crop management: the longitudinal rope-wick applicator; the transverse rope-wick applicator; and the canvas-wick applicator.

Longitudinal rope-wick applicators are robust and provide a long contact time between the wicks and individual plants while applying herbicide to the back and sides of treated plants. Canvas-wick and transverse rope-wick applicators are less expensive, but are easily damaged in rough terrain, apply chemical to the back side of the plant only and have short contact time with plants (Figure 10).

Figure 10. Handheld weed wick applicator. Image by Steven Manning, Nashville, Tennessee.

The Weed Roller, which is similar to a weed wick applicator, is a drift-free weed control tool that allows its user to apply herbicides directly to targeted species by rolling the herbicide onto the target surface via its rolling sponge head.

In Invasive Plant Management Issues and Challenges in the United States: 2011 Overview; Westbrooks, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2011.

C. High Volume Herbicide Application Equipment

Directed foliar sprays are also applied using wands on hoses attached to spraying systems mounted on vehicles with a much larger capacity. Examples include ATV and RTV mounted sprayers, tractor mounted sprayers, utility skid/trailer sprayers, and aircraft sprayers.

1. ATVs and RTVs

ATV (all terrain vehicles) sprayers are used for selective applications in sensitive areas that are too large for backpack spray procedures. Newly designed sprayers can hold 16, 24 or 40 gallons with optional front tank add on for many ATV models. Boomless nozzles as well as a hose with spray gun can be attached for times when the applicator needs to administer spot treatments. RTVs (rough terrain vehicles, also called Gators) are larger than ATVs and allow the operator to have more capacity for herbicide mixtures. RTVs can hold up to 150 gallon tanks and are a better option when spraying right of ways and larger swaths of herbaceous plants (Figure 11).

Figure 11. ATV and RTV. Image by Steven Manning, Nashville, Tennessee.

ATV Safety

When applying herbicides or mobilizing on a site using an ATV, RTV or other off road vehicle, it is important to understand appropriate safety measures for these tools. Ideally, all practitioners should take a safety course prior to starting work in the field. At a minimum, the field technician should wear an ANSI approved head protective helmet and the appropriate PPE associated with the herbicide being applied.

Downloaded by Randy Westbrooks on September 29, 2011 | http://pubs.acs.org
Publication Date (Web): September 15, 2011 | doi: 10.1021/bk-2011-1073.ch019

In Invasive Plant Management Issues and Challenges in the United States: 2011 Overview; Westbrooks, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2011.

2. Tractor Mounted Sprayers

Tractor mounted sprayers are the best tool for large prairie restoration and right of way projects. Interchangeable attachments allow the operator to use the tractor for herbicide application as well as seed application procedures. Tractor mounted tanks allow for a much larger workload than other ground equipment with a capacity from 200-600 gallons of spray solution per tank (Figure 12).

Figure 12. Tractor mounted sprayer. Image by Chad Zorn

3. Wetblade Applicators

Wetblade Applicators are mowers with a cutting deck and a built-in sprayer to deliver herbicides to target vegetation during mowing. Wetblade mower systems can also be used to deliver some biocontrol agents. This can be an effective way to integrate biological with mechanical control of invasives under certain conditions. Wetblade devices can also be added to other cutting tools such as modified brush cutters that cut and treat stumps simultaneously. In general, control has been inconsistent with the current technology.

4. Utility Skid/Trailer Sprayers

Utility skid/trailer sprayers often have a 100-150 gallon capacity. Non-native plant management usually requires that a 100-200 foot hose with handgun and reel be attached to the sprayer for instances when the applicator must trek into the infestation on foot (Figure 13).

Downloaded by Randy Westbrooks on September 29, 2011 | http://pubs.acs.org
Publication Date (Web): September 15, 2011 | doi: 10.1021/bk-2011-1073.ch019

In Invasive Plant Management Issues and Challenges in the United States: 2011 Overview; Westbrooks, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2011.

Figure 13. Utility skid/trailer sprayer. Images by Steven Manning, Nashville, Tennessee.

Skid sprayers are a good tool to use for spraying invasive plants that are not accessible by vehicle. Tanks can hold up to 200 gallons of solution and the applicator can utilize up to a 200 foot hose to access hard to reach areas.

5. Roadside and Turf Sprayers

Roadside and turf sprayers have a much larger capacity than tractor mounted sprayers and generally range from 500-3,000 gallons. Roadside sprayers are often custom designed to fit onto a work truck and are the most efficient way to spray roadsides (Figure 14).

Figure 14. Roadside sprayer. Image by Art Gover,

In Invasive Plant Management Issues and Challenges in the United States: 2011 Overview; Westbrooks, R., et al.; ACS Symposium Series; American Chemical Society: Washington, DC, 2011.

Downloaded by Randy Westbrooks on September 29, 2011 | http://pubs.acs.org
Publication Date (Web): September 15, 2011 | doi: 10.1021/bk-2011-1073.ch019

6. Helicopter Sprayers

Helicopter sprayers offer a unique and selective way to apply herbicides on larger, remote sites where non-natives exist. With GPS technology helicopter applicators can be extremely precise in controlling target vegetation. They are highly maneuverable and apply sprays at much slower speeds than fixed-wing aircraft. Spray tanks vary in size from 90 - 230 gallons. Many types and sizes of nozzles are available (Figure 15).

Figure 15. Helicopter sprayer. Image by Clayton Ferrell. Tennessee National Wildlife Refuge, U.S. Fish and Wildlife Service, Paris, Tennessee.

7. Fixed Wing Aircraft Sprayers

Fixed wing aircraft sprayers (often called crop dusters) with spray booms mounted below the lower wing have been used effectively to apply herbicidal sprays over extensive areas to control brush and weeds since the 1950s. They have larger payload capacities and greater airspeeds than helicopters. Spray tank capacities vary from 400 - 800 gallons. GPS/GIS systems are helpful for precision applications. Fixed-wing planes are not suited for spraying highly irregular shaped sites or mountainous areas and require a nearby airport to be efficient.

8. Large Fixed Wing Aircraft Sprayers

Large fixed wing aircraft sprayers include specially-modified C-130H aircraft and Modular Aerial Spray Systems (MASS.) The MASS systems are designed for specially-modified C-130 aircraft, used to spray biting insects such as mosquitoes, sand fleas, and filth flies. The systems are also used to control vegetation growth on military bombing ranges. Although such services are available nationwide, there are few management areas sizeable enough to utilize such a service in the eastern United States (Figure 16).

As an example, one project conducted by the Air Force Reserve's 910th Airlift Wing in Youngstown, OH, sprayed 2,880,662 acres, or 4,501 square miles - an area equivalent in size to the state of Connecticut. A total of 14,000 gallons of

In Invasive Plant Management Issues and Challenges in the United States: 2011 Overview; Westbrooks, R., et al.; ACS Symposium Series; American Chemical Society: Washington, DC, 2011.

Downloaded by Randy Westbrooks on September 29, 2011 | http://pubs.acs.org
Publication Date (Web): September 15, 2011 | doi: 10.1021/bk-2011-1073.ch019

pesticides were used and the missions comprised 191.4 hours of total flying time with 46.5 hours of actual "Spray-On" time flying at 150 feet above ground level.

Figure 16. Large fixed wing aircraft sprayers. Image by Ron Nehrig and Karl Haagsma,

Downloaded by Randy Westbrooks on September 29, 2011 | http://pubs.acs.org
Publication Date (Web): September 15, 2011 | doi: 10.1021/bk-2011-1073.ch019

IV. Other Selective Herbicide Application Methods

Although treating extensive inaccessible infestations may require broadcast treatments by helicopter or tractor-mounted application systems, the best approach is usually selective applications of herbicides to target nonnative plants while minimizing off target impact to desirable plants.

A. Stem Injection

Stem injection (including hack and quirt) is a selective method of controlling larger trees and shrubs (more than 2 inches in diameter) with minimum damage to surrounding plants (Figure 17). Cut surface treatments are sometimes not as effective in controlling root suckering as basal bark treatment, but may be easier to use in remote or difficult terrain where using a backpack would be difficult. Use this method during the summer or sprouting and suckering will be more likely to occur.

In Invasive Plant Management Issues and Challenges in the United States: 2011 Overview; Westbrooks, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2011.

Figure 17. Cut surface treatments – hack and squirt. Images by Steven Manning, Nashville, Tennessee.

Spaced injection, usually as the hack and squirt method, is the fastest and most effective for treating non-native trees such as tree-of-heaven [*Ailanthus altissima* (P. Mill.) Swingle]. Injection cuts are generally spaced about 1.0 - 1.5 inches apart around the circumference of the trunk at any convenient height. Hand-held, chemical resistant 1 - 2 quart spray bottles are commonly used for applying 0.5 - 2 milliliters of concentrated herbicide or herbicide dilution into the incisions. Incisions should be angled downward to hold the herbicide, and must be deep enough to penetrate the bark and cambium layer. A complete girdle or frill is not needed or desirable.

Completely frilling the stem with edge-to-edge cuts or injections is required for very large stems or difficult to control species. Multiple cuts should not be made directly above or below each other because this will inhibit movement of the herbicide. Herbicide is applied to each cut until the exposed area is thoroughly wet. The herbicide should remain in the injection cut to avoid wasting herbicide on the bark and to prevent damage of surrounding plants. Machetes are useful in clearing a path in thick vegetation and in creating a wound in a wooden stem for chemical injection (Figure).

Figure 18. Manual control with a machete. Images by Steven Manning, Nashville, Tennessee.

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 consists of a steel hatchet connected to a herbicide container (worn on belt) by tubing (Figure 19). The injector delivers 1 milliliter of

In Invasive Plant Management Issues and Challenges in the United States: 2011 Overview; Westbrooks, R., et al.; ACS Symposium Series; American Chemical Society: Washington, DC, 2011.

Downloaded by Randy Westbrooks on September 29, 2011 | http://pubs.acs.org
Publication Date (Web): September 15, 2011 | doi: 10.1021/bk-2011-1073.ch019

herbicide into the cut. The Hypo Hatchet is not generally suitable for backcountry use because the supply line is easily tangled and prone to separation from the supply tank.

Figure 19. Hypo Hatchet® – tree injector. Image by Steven Manning, Nashville, Tennessee.

Another injector is the EZ-Ject®, which consists of a steel lance that holds 400 shells of glyphosate or imazapyr herbicides (Figure 20). 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. Shell jamming has been reported as a persistent problem when using the EZ-Ject® to treat extensive infestations, which may limit this tool to occasional use.

Figure 20. EZ-Ject® Chemical Injector. Images by Steven Manning, Nashville, Tennessee.

Tree injection treatments are most effective when applied throughout summer and into late winter. Heavy spring sap flow can wash herbicide from incision cuts, making this an ineffective period. All injected herbicides can be transferred to untreated plants by root grafts and uptake of root exudates. Herbicides with soil

In Invasive Plant Management Issues and Challenges in the United States: 2011 Overview; Westbrooks, R., et al.; ACS Symposium Series; American Chemical Society: Washington, DC, 2011.

Downloaded by Randy Westbrooks on September 29, 2011 | http://pubs.acs.org
Publication Date (Web): September 15, 2011 | doi: 10.1021/bk-2011-1073.ch019

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. Use chemicals that do not travel in the soil to limit off target mortality.

B. Cut-Treatments

Cut-treatments involve herbicide concentrates or herbicide-water mixtures applied to the outer circumference and sides of large freshly cut stumps or the entire top surface of small cut stems, applied with a spray bottle, wick, or paint brush. Freshly cut stems and stumps of woody stems, including canes, vines, and bamboo, can be treated with herbicide mixtures to prevent resprouting and to kill roots, and should be treated immediately after the cut. Cutting is usually done with a hand saw or with cutting tools such as a chain saw or a brush saw.

Downloaded by Randy Westbrooks on September 29, 2011 | http://pubs.acs.org
Publication Date (Web): September 15, 2011 | doi: 10.1021/bk-2011-1073.ch019

***PPE--Gloves**: While many choices of gloves are available, invasive plant control projects most often require chemical resistant neoprene or nitrile gloves for herbicide application and sturdy leather gloves for mechanical tools. Refer to the herbicide label when considering the type of glove required for specific chemicals.*

1. Chainsaws

Most non-native invasive plant control requires a 12-14" bar. It is a good idea to use professional lightweight models when choosing a saw. Professional "Tree" saws are usually the lightest on the market (Figure 21).

2. Brush Saws

Brush saws are weed eaters with a blade for a cutting device. While many large and expensive brush clearing saws can be found in the market, the high end professional weed eater is what is usually needed for non-native invasive plant control projects. Special blades are available at most dealers. Saw tooth blades are the best for controlling non-native invasive plants and can be re-sharpened throughout the life of the blade.

In Invasive Plant Management Issues and Challenges in the United States: 2011 Overview; Westbrooks, R., et al.; ACS Symposium Series; American Chemical Society: Washington, DC, 2011.

Figure 21. Cut stump treatments. Images by Steven Manning, Nashville, Tennessee.

To minimize deactivation of the herbicide, sawdust should be removed from cut stumps before treatment. Cut Stems and stumps should be treated as quickly as possible with a utility spray bottle for spray applications. Small stems should be treated with a wick applicator, lab wash bottle, or paintbrush. For stumps over 3 inches in diameter, the outer edge should completely saturated with the herbicide solution, allowing some to run down the sides. The tops of smaller stumps and cut stems in a clump should be completely covered with herbicide. Cut stumps and stems that have remained untreated for over two hours should be treated with a basal spray mixture of herbicide, oil, and penetrant, or completely covered with Pathfinder II® (triclopyr).

The most effective time for the stump spray method is summer and fall. Although winter treatments are slightly less effective than growing season applications, the absence of foliage on cut stems and branches produces some offsetting gains in application efficiency.

Note: Do not cut and treat stems more than 3 inches from the ground. Applying herbicides to taller stumps will decrease mortality as the herbicide has to move further to buds and root tips.

C. Basal Sprays

Basal sprays are herbicide-oil-penetrant mixtures sprayed or daubed onto the lower portion of woody stems, usually applied with a backpack sprayer or wick applicator. Basal sprays are best where most trees are less than 8 inches in diameter, but can be used on much larger trees as well. Application is made to smooth juvenile bark by thoroughly wetting the lower 10 - 24 inches of the trunk, up to 36 inches on larger trees, to the ground line, including the root collar area and any exposed roots. Avoid spray contact with desirable trees or heavy use within their root zone. The herbicide must be in an oil-soluble formulation (diesel fuel, fuel oil, mineral oil, vegetable oil, or special basal oil products) and if not in a ready-to-use form it may be mixed with specially formulated penetrating oil. Use an adjustable cone nozzle in a coarse spray, or a B&G Basal Wand with a Y3 (or X3) tip, or 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 40.02E, oriented cross-wise to the wand. All backpack sprayers and spray guns should have chemical resistant seals for the herbicides and carriers being used. Herbicides that are soluble in oil (mainly Garlon 4) are mixed with a commercially available basal oil, vegetable oil, crop oil, diesel fuel, or kerosene often adding a special

Downloaded by Randy Westbrooks on September 29, 2011 | http://pubs.acs.org
Publication Date (Web): September 15, 2011 | doi: 10.1021/bk-2011-1073.ch019

In Invasive Plant Management Issues and Challenges in the United States: 2011 Overview; Westbrooks, R., et al.; ACS Symposium Series; American Chemical Society: Washington, DC, 2011.

penetrant. Some herbicides, such as Pathfinder II and Vine-X, are sold ready to-use with these ingredients. Once treated, wait at least 6 months before cutting dead trees. Fall, winter and late spring applications are often not as effective, though the period from Feb. 15 – April 1 is acceptable. The best time is June 1 – Sept. 30 (Figure 22).

Figure 22. Basal bark spray treatment. Image by Steven Manning, Nashville, Tennessee.

A modified method, called streamline basal sprays, is effective for many woody species up to 2 inches in diameter, as well as trees and shrubs up to 6 inches in diameter if the species is susceptible. The equipment needed for this treatment is a backpack sprayer with a spray gun and a low-flow straight-stream or narrow-angle spray tip. To prevent waste, maintain pressure below 30 pounds per square inch with a pressure regulator. At this pressure, an effective reach of 9 feet is possible while bark splash is minimized. For stems less than 2 inches in diameter, the stream of spray should be applied up-and-down single stems for about 6 to 8 inches, or applied across multiple stems in 2-3 inch-wide bands. This same multiple band treatment can be effective on larger stems. Direct the spray stream to smooth juvenile bark at a point about 4 - 18 inches from the ground. Stems that are thick barked or near 3 inches in diameter require treatment on all sides. Applications are usually in late winter and early spring, when leaves do not hinder spraying the stem. Summer applications are effective but more difficult. Avoid ester herbicide formulations on hot days to prevent vapor drift injury to non-target plants.

In Invasive Plant Management Issues and Challenges in the United States: 2011 Overview; Westbrooks, R., et al.; ACS Symposium Series; American Chemical Society: Washington, DC, 2011.

Downloaded by Randy Westbrooks on September 29, 2011 | http://pubs.acs.org
Publication Date (Web): September 15, 2011 | doi: 10.1021/bk-2011-1073.ch019

D. Soil Spots

Spots of soil-active herbicide [e.g., Velpar L® (hexazinone) and Hyvar X-L® (bromacil)] are applied as metered amounts to the soil surface in grid patterns around target woody stems or in a grid pattern for treating many stems in an area are usually applied with a spray bottle or with a backpack sprayer equipped with a straight-stream nozzle. This method requires exact amounts and prescribed spacing's that are specified on the herbicide label or label supplements. It is only effective on specific nonnative plant species and usually only when applied in spring and early summer (Figure 23).

Figure 23. Soil spot treatment. Images by Steven Manning, Nashville, Tennessee.

E. Thinvert Application System

The THINVERT Application System® combines a series of spray nozzles with a thin invert emulsion spray fluid which controls spray drift and reduces evaporation of airborne sprays. It is a good tool for low-volume sprays to right-of-way brush foliage, stems, or cut stumps. THINVERT forms a more stable droplet, which does not readily break up into finer droplets as water droplets do when released into the atmosphere. THINVERT carriers are usually only slightly more viscous than typical oil carriers (Figure 24).

Figure 24. Thinvert Application System. Images by Steven Manning, Nashville, Tennessee.

In Invasive Plant Management Issues and Challenges in the United States: 2011 Overview; Westbrooks, R., et al.; ACS Symposium Series; American Chemical Society: Washington, DC, 2011.

Downloaded by Randy Westbrooks on September 29, 2011 | http://pubs.acs.org
Publication Date (Web): September 15, 2011 | doi: 10.1021/bk-2011-1073.ch019

F. Pneumatic Applicator Equipment for Herbicide Ballistic Technology

Currently, new equipment options are under development at the University of Hawaii for control of invasive plants in hard to reach areas such as hillsides and ravines with herbicide filled paint balls that are dispensed with paintball guns (Figure 25). From the ground or helicopter, sharpshooters treat target plants with herbicide filled capsules in a very selective manner. This very selective control option also creates an easier to use measurement system for herbicide application – *no mixing is required*.

Figure 25. Herbicide ballistic technology. Images by Steven Manning, Nashville, Tennessee.

V. Summary

In many cases, the most effective method for control of an invasive plant in natural areas involves the use of herbicides. Once it is determined that chemical control is the preferred method for controlling an invasive plant, the next step is to determine what kind of herbicide should be used. Most herbicides are applied as a spray to target vegetation or to the soil around a target species (where it is taken up by the plant root system). Adjuvants and additives are added to a herbicide mix to enhance its effectiveness – to help it stick to the plant surface, or to help it penetrate into the plant tissues. The final step in planning for an herbicide treatment is to determine how it should be applied to target vegetation. Low volume or high volume sprayers are normally used to apply herbicides, depending on the size of the target area. However, in some cases, other selective application methods such as cut treatments (hack and squirt), stem injection, and basal bark treatments are used to minimize off-target impacts. Herbicide ballistic technology which uses paintball guns to apply pre-mixed herbicides in paintball pellets is a new method

In Invasive Plant Management Issues and Challenges in the United States: 2011 Overview; Westbrooks, R., et al.; ACS Symposium Series; American Chemical Society: Washington, DC, 2011.

Downloaded by Randy Westbrooks on September 29, 2011 | http://pubs.acs.org
Publication Date (Web): September 15, 2011 | doi: 10.1021/bk-2011-1073.ch019

for applying herbicides to target species in hard to reach areas such as hillsides and ravines. In all cases, the proper use of application equipment ensures that herbicide sprays are dispensed correctly and effectively.

Downloaded by Randy Westbrooks on September 29, 2011 | http://pubs.acs.org
Publication Date (Web): September 15, 2011 | doi: 10.1021/bk-2011-1073.ch019

In Invasive Plant Management Issues and Challenges in the United States: 2011 Overview; Westbrooks, R., et al.;
ACS Symposium Series; American Chemical Society: Washington, DC, 2011.