UF IFAS Extension UNIVERSITY of FLORIDA

FOR273

Considerations for Developing Effective Herbicide Prescriptions for Forest Vegetation Management[1]

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Introduction

This paper is intended to review important considerations in developing effective and environmentally sound herbicide recommendations for managing vegetation in forests. It is intended for use by private forest land owners, foresters, and other land managers.

Developing an herbicide treatment prescription is a complex process that involves matching a suitable herbicide program with a specific silvicultural operation and an overall management objective. One should attempt to select the herbicide program that can be expected to provide effective weed control with minimum environmental or other hazards at the lowest cost. The herbicide treatment must also fully comply with product labels and other regulatory constraints. Therefore, in developing a site-specific herbicide treatment, the forest manager must carefully consider:

- Overall management objectives
- Objective of the intended silvicultural operation
- Site location, dimensions, and size
- Accessibility to the treatment area
- Appropriate application method (aerial, ground equipment, hand-held)
- Desirable or crop tree species
- Weeds present or expected
- Soil and site conditions affecting herbicide behavior
- Sensitive areas (adjacent crops, homes, bodies of water, etc.)
- Hazards to applicators (such as power lines, open wells, etc.)
- Available herbicides and label recommendations for the intended use
- History of vegetation management on that site to avoid developing herbicide-resistant weeds or encountering herbicide residual problems

The prescription should include:

- Date the recommendation was made
- Description of the location and accurate treatment area measurement
- Herbicide products to be used
- Application rate(s) in both amounts of product and amounts of active ingredient per acre, hectare, or other measure of area treated
- Application method
- Application timing
- Special precautions to protect the environment and provide worker safety

1. This document is FOR273, one of a series of the School of Forest Resources and Conservation Department, UF/IFAS Extension. Original publication date October 2010. Revised May 2011 and June 2017. Visit the EDIS website at http://edis.ifas.ufl.edu.

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- Other integrated vegetation management recommendations such as prescribed burning
- Name, address, and pesticide applicator license number of the person making the recommendation as required by state and local law

In this discussion, both the herbicide **active ingredient** (starting with a lower case letter) and one or two examples of **trade names of herbicide products** (starting with a capital letter, usually in parenthesis) will be given. For example, imazapyr (Arsenal® AC, Chopper®) indicates that both herbicide products named Arsenal® AC and Chopper® contain the active ingredient imazapyr. Inclusion of a product trade name in this publication does not constitute an endorsement of a product or a company, as other products manufactured by different companies might be equally suited for the intended herbicide use. Numerous products are available that contain the same active ingredient or ingredients, but the reader should be aware that there might be considerable differences among product formulations, even among herbicide products with the same concentration of the same active ingredient(s). **The label directions on the specific product container being used are the law.**

Silvicultural Operation

Herbicides are most often used for the following silvicultural operations, which are described in more detail in this section:

- Site preparation before tree planting
- Herbaceous weed control for plantation establishment after tree planting
- Release of established pine trees from competing woody vegetation later in the rotation
- Mid-rotation release to enhance pine growth
- Late-rotation release before harvest to initiate site preparation
- Timber stand, wildlife habitat, or aesthetic improvement

SITE PREPARATION

Controlling vegetation prior to planting, especially perennial woody vegetation and grasses, is crucial for successful plantation establishment. Herbicides used for this purpose are generally **non-selective** or **broad-spectrum**, meaning that they control many species. However, they should also not injure trees planted after application. Herbicide labels contain specific guidelines for time intervals between site preparation and tree planting for various crop tree species.

Site preparation herbicides are often persistent and **soil active**, meaning that they are absorbed by plant roots from the soil. Some site preparation treatments include **long-residual** soil active herbicides such as sulfometuron methyl (Oust® XP, SFM 75), imazapyr (Arsenal® AC, Chopper®) and hexazinone (Velpar® L, Velpar® ULW), which may provide some level of weed control for months following planting.

HERBACEOUS WEED CONTROL AFTER PLANTING

Once the trees have been planted, the choice of herbicides is more limited because most of the time **selective** herbicides, which target specific weeds or weed groups but do not significantly injure crop trees, must be used. These herbicides are commonly applied **over-the-top** of planted trees, either in a **banded application** (usually 4–6 feet wide over tree rows), or over individual seedlings in a circular area, an approach known as **tree-centered spot** treatment. An exception would be the use of a broad spectrum, non-selective herbicide such as Accord® XRT II (glyphosate) applied as a **directed spray** to the foliage of weeds while avoiding any contact with the crop trees. This herbicide is **foliar active** and therefore absorbed only through the foliage and stems, so selectivity is achieved by avoiding spray contact with desirable trees. Grasses and forbs are the primary weed species targeted in herbaceous weed control, but some products, such as imazapyr (Arsenal® AC, Chopper®) or hexazinone (Velpar® L, Velpar® ULW) also partially control woody plants at the low herbicide rates used for selective weed control in young pine stands.

RELEASE TREATMENTS

Release treatments are common in pine silviculture to remove unwanted hardwood trees and shrubs using selective herbicides over-the-top of crop trees or by directing non-selective herbicides to unwanted brush. Release treatments are normally done either during the first 2–5 growing seasons after planting, at mid-rotation (8–20 years), or a few years prior to harvest. Release treatments using herbicides may also be done in hardwood silviculture. The objective of release treatments is to re-allocate available resources supporting growth (light, nutrients, and water) to foster the growth of the more valuable or otherwise desirable trees in the stand.

TIMBER STAND, WILDLIFE HABITAT, AND AESTHETIC IMPROVEMENT

An array of herbicide treatments may be employed to enhance timber or other values in established conifer or hardwood stands. Most approaches involve applying

herbicides to individual plants deemed undesirable for the management objective, thus removing competition for desired trees. Herbicides may be applied to the foliage as directed sprays or to the woody tissues as **basal bark sprays**, by **frill girdle (hack and squirt)**, **injection** or **cut stump** methods. Soil-active herbicides can be used for **basal soil** application in close proximity to the stems of target vegetation, but should not be applied to areas where the roots of desirable vegetation may extend.

Location, Access, Size of Treatment Area, and Application Method

Several operational constraints are considered in choosing the most cost-effective treatment for silvicultural herbicide operations. A detailed topographic map, soils map, recent aerial photograph, and GPS locations should accompany forest managers while making treatment prescriptions on-site. The treatment prescription and application planning should be done well in advance of actual treatment. Access roads and gates should be noted, and it is best to have more than one alternative route to the treatment area. Often it is necessary to use large volumes of water in spray applications, so road access, bridge weight capacity, and clearance under tree limbs should be considered to accommodate batch trucks.

Many problems in herbicide performance, crop tree injury, and off-target application have resulted because the treatment area was poorly delineated or because of inaccurate measurement of the treatment area. The availability of GPS equipment for pre-treatment area surveys and for guidance during application facilitates accurate area measurements and thus precision in applying prescribed herbicide rates. A time-tested technique in site preparation application is to plow a fire line around the treatment area, which can be seen by ground or aerial applicators. This also facilitates post-herbicide broadcast site preparation burning, if desired. In young stands, the treatment area may be delineated with a fire plow line or by placing white plastic bags on the top of vegetation about 100 feet apart at the spray boundaries. In older stands with closed canopies, GPS guidance may be supplemented by suspending helium-filled balloons attached to fishing pole lines through the forest canopy at the corners of the treatment area.

The size of the treatment area must be considered in choosing the most cost-effective application method, which may involve backpack application, mechanical ground sprayers, or aircraft. Generally, small treatment areas (less than 50 acres) preclude aerial application unless several nearby areas are treated in the same operation. For small treatment areas (20 acres or less), backpack application is often most feasible, but brush should be less than shoulder high, and for the greatest conservation of labor and herbicide, brush should be no more than waist high. Consider brush density as well: some brush-fields become so dense that they are impassible by ground crews and must be treated with heavy ground equipment or by aircraft.

Crop Trees

Herbicide tolerance varies by crop tree species, age, and stage of growth. Obviously, herbicide tolerance is crucial when making applications over-the-top of crop trees as in herbaceous weed control or pine release operations. It is also important in site preparation applications when persistent soil-active herbicides such as imazapyr (Arsenal®AC, Chopper®) or hexazinone (Velpar® L, Velpar ULW) are used.

Herbicide manufactureres normally list specific herbicide recommendations for each crop tree species, although some labels are very general and may just state "for use in conifers." Of the three most commonly cultivated pine species in the southeast, loblolly pine is generally the most tolerant to forestry herbicides, whereas longleaf pine is the least tolerant and slash is intermediate in herbicide tolerance. Therefore, fewer herbicides can be safely applied in longleaf or slash pine than in loblolly pine plantations. For example, Escort® XP (metsulfuron methyl) or Aatrex® Nine-O (atrazine) are labeled for use in loblolly and slash, but not for longleaf pine. Some herbicides, such as Arsenal® AC or Chopper® (imazapyr), should be applied at lower rates for slash and longleaf pine to prevent terminal dieback and inhibition of height growth. Additionally, when making herbaceous weed control or release applications over slash or longleaf pine seedlings with imazapyr, a surfactant (wetting additive) should not be added because surfactants increase foliar absorption by pines and thus may increase crop tree injury.

The degree of crop tree sensitivity to many herbicide products also depends on tree age and growth phase. In general, the youngest pines are the most sensitive. Therefore, sensitivity of crop tree species is especially critical in designing herbaceous weed control treatments because herbicides are applied over-the-top or in the vicinity of young pine seedlings. Surfactant-free Arsenal® AC (imazapyr) has to be used at very low rates during the first two growing seasons after planting longleaf or slash pine seedlings. In general, pine sensitivity to herbicides increases during periods of active growth. Slash pine is particularly sensitive to herbicide applications during and immediately

following growth flushes, and newly elongated shoots may die back as a result of imazapyr application. Physiological condition and vigor of crop trees also affect their herbicide tolerance. Trees under stress caused by drought, prolonged flooding, disease, insect infestation, animal damage, etc., are more likely to be damaged by herbicides.

Weeds

For the purpose of this publication, the word "weed" is defined as any undesirable plant. Herbicides are used to control weeds, but may be useful in promoting desirable non-crop vegetation as well. For example, the use of imazapyr (Arsenal® AC) will promote the growth of legumes, which are tolerant to this herbicide and often desired as a wildlife food source. Another example in which desirable associated plants are promoted is application of hexazinone (Velpar® L, Velpar® DF) in longleaf ecosystem restoration, whereby tolerant native grasses (such as broomsedge) are favored. In selecting the appropriate herbicide or combination of herbicides it is important to consider plants that are particularly susceptible to a given herbicide, as well as those plants that will not be controlled.

A large body of research has shown that a very high degree of vegetation control is needed to optimize crop tree growth. For this reason, herbicides that provide a broad spectrum of control and long residual activity are most effective in accomplishing the objective of enhancing timber production. It is critical to identify and quantify dominant weed species on the site before prescribing a herbicide treatment. The urgency of controlling a particular species depends not only upon its density on the site, but also on its size, growth habit, vigor, potential for re-growth and spreading, allelopathy (toxicity to other plants), or status as an invasive plant or known alternative host of an important disease. Cogongrass, for example, is such a noxious weed that even a very small amount of cogongrass justifies prescribing herbicide treatment in an attempt to eradicate it from the site before it spreads more widely. When assessing the vegetation complex on the site, it is necessary to inspect the surrounding area for weeds that may invade the site in the future. It is also useful to know the land use history and the pattern of weed development on similar sites with the same history. Weed seeds and vegetative parts may survive in the soil for a very long time and become a problem on the site once conditions for their growth are favorable. Most tree and shrub competitors on forestry sites grow from stump sprouts or sprouting root systems, but they may also arise from seed present in the soil or seed introduced by wind, birds, or other animals.

Prioritizing weed species for herbicide control and designing effective herbicide treatments requires familiarity with weed taxonomy and growth cycles. Taxonomically, most weeds important in forestry are vascular plants. Within this group a few are ferns (e.g., Japanese climbing fern), some are gymnosperms (represented by conifers), but the majority are angiosperms (flowering plants). The angiosperms are divided into two classes: **monocots** (including **grasses**, sedges, rushes, palms, and yuccas) and **dicots** (**broadleaf** plants). Several herbicides, such as glyphosate (Accord® XRT II, Gly Star® Pro), imazapyr (Arsenal® AC, Chopper®), and hexazinone (Velpar® L, Velpar® ULW), control both broadleaf weeds and grasses. Some are effective primarily against broadleaves, for example triclopyr (Garlon® 3A, Garlon® 4), 2,4-D (Barrage® HF, DMA® 4 IVM), clopyralid (Transline®, Clean Slate®), dicamba (Vanquish®), fluroxypyr (Vista® XRT) or only grasses, e.g., fluazifop-P-butyl (Fusilade® DX) and clethodim (Envoy Plus™). Most products are less effective in controlling conifers than angiosperms. If residual pines have to be controlled during site preparation, glyphosate (Accord® XRT II), aminopyralid (Milestone® VM), or a combination of these herbicides are applied, often followed with prescribed burning.

Based on the length of their life cycle, weeds can be classified as **annual** (completing the life cycle within a year), **biennial** (surviving two years), or **perennial** (living for more than two years). There are numerous species of annual and perennial broadleaf weeds, grasses, and sedges. Relatively few weed species are biennial. Some herbicides, such as atrazine (Aatrex® 4L), paraquat (Gramoxone Inteon®), simazine (Sim-Trol® 90DF), and pendimethalin (Pendulum® 2G) are generally only effective in controlling annual weeds. However, in an established plantation, perennials, especially shrubs and hardwood trees, are usually the most prevalent weeds. They are also most difficult to control because of their great persistence and reproductive potential.

Based on their habitat we can distinguish two major weed categories: terrestrial (growing on land) and aquatic (growing in water) with the subcategories: floating, emerged, and marginal between aquatic and terrestrial.

Besides systematic classifications, herbicide recommendations often refer to practical weed categories. **Brush** is a term for unwanted shrubs and small trees. **Vines** are plants with climbing or creeping stems. **Brambles** include several species in the genus *Rubus* (blackberries, dewberries, and raspberries), usually characterized by thorny or bristly stems. Sometimes wild rose (*Rosa* spp.) is placed in the

same category. **Forbs** is a term often used for herbaceous broadleaf plants.

Various herbicide labels group weeds in different ways in the "**Weeds Controlled**" section. On most labels, woody plants are listed separately. In some cases, vines and brambles are considered a special category (e.g., on the Arsenal® AC label) because of a particular difficulty in controlling them. On some labels, there is only a distinction between herbaceous and woody plants (e.g., Velpar® L). In other cases, the distinction is also made between grasses and broadleaf species or between annual and perennial weeds.

Sometimes the "weeds controlled" section of herbicide labels gives information regarding the susceptibility of various species, rating them from "highly susceptible" to "resistant" (meaning tolerant—it does not refer to the development of genetic weed resistance, a separate phenomenon discussed below). Most weeds fall between these two extreme categories, but it may be hard to accurately specify intermediate degrees of weed control by a given product because the degree of control also depends on weed density, size, and maturity, as well as herbicide application rate and a host of site factors. Hard-to-control species or dense, larger, or more mature weeds require higher recommended herbicide application rates to obtain the same degree of control compared with more susceptible species, or sparse, smaller, less mature plants.

Application of herbicide mixtures is often necessary to obtain the desired degree of weed control. This is especially true where diverse vegetation is present on a site. Generally, combinations of herbicides will provide a greater spectrum of weed control than a single herbicide. Another very important reason to use combinations of herbicides, particularly those with different modes of action, is to reduce the potential that weed populations will develop genetic herbicide resistance. Herbicide resistance is of particular concern with repeated applications of herbicides with a very specific site of action, such as the amino acid inhibitors: glyphosate (Accord® XRT II), sulfometuron methyl (Oust® XP), imazapyr (Arsenal® AC), or photosynthesis inhibitors: hexazinone (Velpar® L) or atrazine (Aatrex® 4L). The physiological response to herbicides should also be considered to ensure effectiveness. For example, herbicides that produce rapid desiccation of the foliage, such as paraquat (Gramoxone Inteon®) should not be combined with translocating herbicides such as glyphosate (Accord® XRT II), which require time to be absorbed by the leaves and transported within the plant. An understanding of herbicide mode of action and plant physiology will support the selection of complementary herbicide combinations.

Although any combination of herbicides can be legally mixed if each is labeled for the intended application and the mix is not prohibited by any of the labels, it is important to select compatible products and mix them properly. Some labels provide recommendations for acceptable herbicide combinations and instructions for mixing. Improper herbicide mixing may result in phase separation (e.g.) when mixing Accord® XRT II and Garlon® 4 at high rates) or even herbicide deactivation (e.g. when mixing Envoy Plus™ with many other herbicides). When using a combination for the first time it is advisable to do a "jar test" by mixing small amounts of the products in the appropriate proportion to test for physical compatibility. For herbicide mixtures, one has to use the most restrictive limitations from labels of all mixed products.

Soil Conditions

The efficacy and environmental safety of soil-active herbicides strongly depend on the soil texture, organic matter content, pH, soil drainage properties, and presence or absence of a hardpan. Fine-textured soils (clays) and organic soils have higher adsorptive capacity than coarse-textured (sandy) soils. Therefore, soils with high clay and/or organic matter content have a higher capacity to bind herbicides, making them less available for uptake by plant roots. As a result, higher herbicide rates may be necessary to obtain a satisfactory degree of weed control on these soils. On the other hand, on sandy soils, lower herbicide rates should be applied to avoid damage to crop trees and/or herbicide leaching to groundwater. Most soil-active herbicide labels provide rate recommendations for various soil types. When the treatment area has very different soil types, more than one prescription may be necessary.

Soil pH also affects activity and mobility of some herbicides. For example, sulfometuron methyl's (Oust® XP) water solubility, and thus herbicide mobility and plant uptake, increase significantly at pH values above 6.1. This changes the selectivity to pines in herbaceous weed control applications, and lower rates must be used. Presence of a soil hardpan, especially a shallow one, may also restrict the use of soil-active herbicides for pine release. It increases the danger of pine mortality, since pine roots tend to spread out at the level of the hardpan, where the herbicide may concentrate.

Sensitive Areas

When prescribing herbicide treatment, one has to seriously consider all potential effects, not only with regard to the target site, but also to adjacent sites. Of particular concern are such sensitive areas as croplands, grazing lands, wetlands, water bodies, water sources, residences, schools, and public areas. Adverse effects due to herbicide movement from the application site may constitute a label violation and can result in liability litigation. Such movement can occur through drift during application, movement of volatilized herbicide (vapors) during or after application, movement in surface water, leaching to groundwater, or movement with soil particles. These risks can be minimized by selecting herbicides with appropriate active ingredients and formulations, choosing appropriate application methods and timing, and using the lowest effective application rates. Adequate buffers should be established to mitigate drift. In the case of herbicide application near bodies of water, specific Best Management Practices must be followed.

Preventing surface water and groundwater contamination is particularly important. More than 90% of Florida's population depends on groundwater for drinking water. Much of Florida's forestland encompasses aquatic areas or is in groundwater recharge areas. The potential for a herbicide to reduce the quality of surface water through runoff or groundwater through leaching depends on a combination of soil and herbicide properties, along with weather conditions and management practices. In this regard, important soil properties include hydraulic permeability, clay and organic matter content, and slope. Leaching is more likely to occur in flat areas of permeable sandy soils, whereas runoff may be expected on slopes of fine-textured, less permeable soils. The two herbicide properties that most affect the potential to contaminate surface- or groundwater are solubility and persistence.

Most silvicultural herbicides are for terrestrial uses and should not be applied directly to water or to areas where surface water is present. A few exceptions of forestry herbicides labeled for aquatic areas include some surfactant-free glyphosate (Glypro™, Rodeo®) and the imazapyr formulations (Habitat®, Ecomazapyr 2 SL) and some amine formulations of triclopyr (Garlon® 3A, Element® 3A).

Summary

When properly used, herbicides can be an effective tool in forest management without harming the environment. To ensure effective and environmentally sound herbicide use, forest managers should know the limitations of the products they are using. In developing herbicide prescriptions, forest managers should consider herbicide characteristics, vegetation present or expected, soil and other site conditions, the presence of sensitive areas, and appropriate application methods for specific sites. Land managers not familiar with herbicides should seek the advice of professionals. The single most important rule in employing herbicides is to always read and follow the label instructions. An increasing number of labels and SDSs are available in Spanish in addition to the English versions.

Additional Resources

The following websites (accessed June 20, 2017) provide useful information and additional herbicide related links:

- **Crop Data Management Systems** (CDMS) can be searched by the product name for herbicide labels and Safety Data Sheets (SDSs) at http://www.cdms.net/manuf/. Premium search allows for searching by product (trade) name, common name (active ingredient), crop/site, pest (weed species), manufacturer, and state. It can be accessed after a free registration at http://premier.cdms.net/webapls/formsloginRef.asp?/webapls, which should be renewed annually. These searches can also be performed with a mobile application CDMS guide, which is available only for Apple devices for an annual fee of $99.
- **Greenbook Data Solutions** is searchable by label (product name), pest (weed species), manufacturer, crop, active ingredient and, in advanced search, additionally by site and state at https://www.greenbook.net/. After a free registration one can save "My Preferences", which limit search results to the most applicable.
- **National Pesticide Information Retrieval System** (NPIRS) includes information about pesticides either currently or previously licensed for distribution and sale in each state. Information on Florida pesticides registration is updated approximately once a month by the Florida Department of Agriculture and Consumer Services http://state.ceris.purdue.edu/.
- **Environmental Protection Agency** (EPA)–**Office of Pesticide Programs** is an extensive depository of information pertaining to all pesticide related issues with some publications in Spanish. It includes FAQs and a form for asking specific questions http://www.epa.gov/pesticides/.
- **National Pesticide Information Center** contains general, technical, and regulatory information about pesticides and is geared toward the general public with numerous resources in Spanish. Information can be obtained

directly from the NPI in several languages http://npic.orst.edu/index.html.

- **Pesticide Information Office** (PIO) at the University of Florida provides information, educational programs, and materials related to pesticides, including pesticide applicator certification and licensing http://pested.ifas.ufl.edu.
- **UF/IFAS Extension offices** of the University of Florida, Institute of Food and Agricultural Sciences (UF/IFAS) can be contacted with specific questions regarding forestry herbicides http://solutionsforyourlife.ufl.edu/map/.
- **County Foresters** of Florida Department of Agriculture& Consumer Services, Division of Forestry provide technical assistance for forest vegetation management http://www.freshfromflorida.com/Divisions-Offices/Florida-Forest-Service/For-Landowners/County-Foresters

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