EXTENSION

Forest Stand Improvement Practices for Oklahoma

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Preface

Timber Stand Improvement (TSI) is a term that includes forest management intended to improve the composition and structure of a forest stand. It is an intermediate stand treatment where the final goal is harvestable wood products. A stand is a contiguous area of forest that has either a minimum acreage, similar composition (similar species), similar tree density and/or similar tree age or size class. Therefore, a stand is a basic unit of forest that is under the same management. TSI can include any management activity that changes the forest structure and composition of a stand such as prescribed fire, felling individual trees, killing individual or clusters of trees with herbicide, suppressing competing trees, mechanically reducing fuels, limbing trees or controlling invasive species.

TSI generally includes activities prior to a commercial timber harvest but often implies that the TSI activities are intended to improve future timber harvest opportunities. When commercial timber production is not the primary goal, the term Forest Stand Improvement (FSI) is sometimes used to indicate the practices are intended to promote forest goals other than commercial wood products (i.e., timber). This designation is meaningful because it implies the intended focus is on non-timber forest resources. FSI might include goals such as wildlife, aesthetics, watershed, wildfire prevention, livestock grazing and herbaceous vegetation composition. Many of the same practices are used for TSI and FSI, and it is the intent or goal that determines which term is used. FSI will be used in this document except in specific instances where the practice would be most applicable to management intended to improve a future timber harvest, in which case the term TSI is appropriate.

As mentioned above, FSI includes multiple practices that change forest stand structure and composition. However, this document is focused primarily on the management of the forest overstory and midstory (i.e. tree cover) with implications to understory vegetation, wildlife, fuels and livestock forage. Further, this document describes herbicide and mechanical methods; prescribed fire is covered in other documents as are foliar herbicide applications intended to be used on understory vegetation. Specific herbicide recommendations contained within this document use active ingredients rather than trade or brand names unless a specific product is unique to the situation described. We have not included a complete list of all herbicides that may be applicable. Rather, we have chosen herbicides that are widely available, effective and do not require herbicide applicators license. Applicators should familiarize themselves with the chemical composition and formulation of any herbicide product and carefully read the complete herbicide label and safety information before applying.

Why Conduct FSI?

Upland forests are common across much of eastern Oklahoma and in scattered pockets in western Oklahoma. These forests are composed of various species of oak and hickory, shortleaf pine, eastern redcedar, Osage orange, hackberry/sugarberry and elm, among others. Historically, most of these forests experienced frequent fire and many of the trees are fire tolerant (especially oak, hickory and pine). Reductions in fire have shifted the forest composition to more fire intolerant species such as elm and eastern redcedar. Many of these upland forests have more than 80% canopy cover (overstory and midstory combined) allowing limited sunlight to the forest floor. The mature forest overstory consists of trees that are dominant (receiving light from above and the side) or codominant (receiving light from above but little light from the side). These trees have ample light for growth and shade the midstory and understory. The midstory consists of trees that are intermediate (receiving some light from above) and suppressed trees that receive no direct light. The understory consists of the near-ground space in a forest stand and is comprised of vines, shrubs, forbs, grasses and a litter layer, dependent on the amount of light reaching the forest floor. Smaller diameter (more than 7-inches) trees and fire-intolerant species are most susceptible to fire and fire is often used to manage forest structure and composition. However, fire-tolerant species such as post oak, blackjack oak, black oak and hickory species in the mid- and overstory can persist for many decades, even with frequent fire. Therefore, using herbicide and/or mechanical methods may be preferable to quickly reduce the midstory and overstory and increase sunlight reaching the forest floor rather than using fire alone.

Opening the overstory results in a dramatic herbaceous, vine and shrub response in the understory. On most sites in Oklahoma, a significant understory response is apparent once overstory/midstory canopy cover is less than 60%. There are a couple of ways that forest overstory thinning can be accomplished. Thinning from above, high thinning or crown thinning all refer to removing dominant and codominant overstory trees. Thinning from below, or low thinning, refers to removing suppressed and intermediate trees. There are pros and cons to each. Thinning from above (TSI) can provide high-quality wood yet can result in high-grading affecting future timber quality. Thinning from below (TSI) can mimic natural self-thinning, yet it does not usually provide any valuable wood. When conducting FSI, since the focus is not on timber products, either thinning from above or below may be desirable, depending on the specific goal. The manager should consider specific goals, tree stem density and size distribution when planning thinning operations.

Regardless of how the thinning is conducted, reducing canopy cover can increase the carrying capacity for many wildlife species and for livestock via increases in forage. White-tailed deer and wild turkey can benefit from selective tree removal to convert closed-canopy forests to open woodlands (defined here as forests with 40-60% canopy cover). While cattle forage can increase with even limited overstory reductions, once canopy cover is less than 40%, warm season grasses benefit, with sunlight reaching a critical threshold of six hours of direct light per day. This dramatically increases the potential for the stand to provide cattle forage. If canopy cover is less than 30%, then bird species such as northern bobwhite, field sparrow and painted bunting will benefit. A savanna (defined here as 5-30% canopy cover) may be desired if goals include bobwhite habitat in addition to cattle grazing.

In unmanaged forest stands, especially when prescribed fire has not been used, encroachment by eastern redcedar (hereafter redcedar) is common. FSI may sometimes be used to reduce redcedar fuel load. Once the initial FSI overstory/midstory thinning is achieved, other FSI treatments, such as prescribed fire, can be more effective to maintain desired conditions over time.

It is important to recognize that the more heavily a forest is thinned, the more frequently fire will need to be used if the goal is to maintain an open forest structure (i.e. woodland or savannah). Without periodic fire, the forest canopy will quickly return to high cover. Periodic evaluations (e.g. every 5-10 years) of canopy cover can help ensure hardwood stands are maintained to the desired level for your goals. Canopy cover can be estimated by averaging several transects throughout the stand. Visit the area when the leaves are on (May-September) around noon when the sun is overhead. Walk a straight line for 200 steps. At every other step, keep a tally of the number of times you are directly under the shade of a tree; this will be your canopy cover for that transect. For example, if 50 of the 100 points were shaded, the canopy cover is about 50%. Should the recorded average canopy cover exceed your target, you may wish to implement additional forest stand improvements.

A local forester or biologist can help you determine canopy cover and provide guidance on selecting trees to remove. When selecting which trees to treat in the forest, recognize forests typically have multiple age/size classes. Diameter limit cutting (i.e., cutting all trees below a certain diameter) can skew the age of the forest and set back

successive generations more than is desirable for future stand composition. Solitary trees that are very crooked, leaning, split or showing obvious signs of disease are logical choices to take if future wood products are desired. However, these trees do have wildlife value, so depending on your goals, you may wish to retain them for cavity nesting species.

While upland forests are often treated with FSI, bottomland forests can also benefit from FSI practices. Bottomland forests occur in or near wetland areas and may be periodically flooded. This includes flats adjacent to rivers and streams, and low-lying basins that experience standing water from runoff and overland flow. Some bottomland forest stands may be sub-irrigated by a water table close to the surface. Bottomland forests often are composed of trees that are not fire-tolerant since the species occurring here seldom experience fire. In Oklahoma, common species encountered in bottomland forests include pecan, cottonwood, willow, boxelder, green ash, sweetgum, pin oak, willow oak and water oak. Historically, these forests had dense canopy cover compared to fire-maintained upland forests. While bottomland forests are often managed for high canopy cover, there are some wildlife species that can benefit from forest openings. Increasing sunlight can increase river cane and vines, which provides food and/or cover for white-tailed deer, swamp rabbits and several warbler species. Forest openings may be used to increase waterfowl use of flooded forests. Felling and allowing hardwood regeneration from root sprouts can improve roosting cover for American woodcock, especially when adjacent to a patchy herbaceous wetland. Even with high canopy cover, cool-season grasses and sedges may provide limited livestock grazing, but opening the canopy can increase the grass biomass of both cool- and warm-season grasses.

Using prescribed fire in bottomland forests to open the canopy can be risky because tree mortality of fire-sensitive species can exceed desired conditions after one fire event. This is especially true if fire has not been used in many years, resulting in a buildup of fuels (dense leaf litter and coarse debris such as logs and large limbs) on the forest floor. Combining herbicide or mechanical methods with individual tree selection to make the initial thinning is generally more practical for bottomland forests. Not only does this avoid the risk of opening the canopy beyond the objective, but it also allows for the retention of desirable trees and removal of undesirable trees depending on the specific goals. Prescribed fire can then be used as needed to maintain the appropriate structure and composition. However, only low intensity fires should be used in bottomland forests if remaining overstory trees will be retained. Although labor intensive over large areas, pulling coarse woody debris several feet away from the base of desirable trees before burning can help reduce the risk of tree injury.

In both upland and bottomland forests, there are many invasive tree, shrub and vine species that should be controlled. Species such as tree-of-heaven, Chinese tallow tree, callery pear (aka Bradford pear), mimosa, privet (various species), nandina, creeping euonymus, English ivy and kudzu are all problematic in Oklahoma forests. Invasive plants take space and resources that could be occupied by more desirable plants and they can form monotypic stands with little plant diversity. This often decreases wildlife diversity and future options for the property. Aggressive invasive plants can also increase management costs to the property owner. Most invasive plants can be individually removed with herbicide application. Many of these plants can also be controlled by fire when young but will resprout once they are established. Therefore, herbicide is typically the preferred treatment for aggressive, invasive plants, yet fire can be helpful to suppress some of them. Additionally, it may be desired to remove or control some native species to favor more desirable species. Examples of native trees that can be aggressive and are often removed include honey locust, redcedar, Osage orange, green ash, boxelder, sweetgum and willow, depending on landowner goals.

FSI Herbicide Techniques

Single Stem Injection | Hack and Squirt | Girdle and Squirt

Single stem injection, hack-and-squirt or girdle-and-squirt are common FSI techniques that allow for individual tree selection and treatment by injuring the outer bark and placing herbicide in the tree. If the objective is to kill large trees but retain most of the overstory (thinning from above), this technique is highly effective. Thinning a stand for white-tailed deer habitat improvement, removing scattered invasive trees, creating individual snags for bats and cavity-nesting birds, and reducing competition for more desirable trees are goals appropriately met with the hack-and-squirt technique. An applicator can treat as little as 0.5 acres to as few as 10 acres per day depending on the number and density of trees that must be treated to meet the goal. While any size tree can be targeted with hack and squirt, trees smaller than 3-inch diameter at breast height (dbh) are not ideal because runoff and drift on small trees is hard to avoid. When large numbers of trees need to be removed, other methods such as soil applied herbicides may be more efficient.

Fall or winter is an excellent time to use this method for many tree species due to cooler weather, low risk of ticks and snakes, and lack of leaves, which makes it easier to move through the forest. However, with tree species that experience winter sap flow on warm, sunny days (e.g. maple), only use this treatment during summer, fall or during cold, cloudy winter days. Also, some species (e.g., those that aggressively root sprout such as tree-of-heaven) appear to be more susceptible to summer treatment. Hack-and-squirt is one of the most commonly used practices for individual tree removal. It involves creating a wound(s) through the bark and into the actively growing part of the tree where a herbicide solution is delivered and translocated by the tree. Avoid using this technique during the spring green-up period when sap is rising in trees (late February – mid-May), because effectiveness may be reduced. Other periods of the year are effective, but overall efficacy varies depending on tree species, season, precipitation, tree stress, herbicide and user application.

Figure 1. Hack and squirt involves putting the herbicide solution directly into a tree wound. Note that the hatchet is used to keep the wound open until the herbicide is fully in the wound. Also note there is no run-off occurring down the tree trunk, because the nozzle has been adjusted and the applicator is not overfilling the wound (see youtube.com/watch?v=P_LKq8V2bHc).

Tools required for small jobs using hack-and-squirt include a squirt bottle and hatchet or machete. Most handheld squirt bottles are calibrated to deliver about 1 milliliter of solution per squirt. However, the chemicals may damage the sprayer, making it unreliable after a few uses. A medium length (16-18 inch), weight-forward hatchet tends to take less effort than a machete and is less likely to cause injury to the applicator. Girdle and squirt is similar except that the entire circumference of the tree is severed in a continuous band. For girdle-and-squirt, a chainsaw may be more efficient than a hatchet or machete. Larger projects may benefit from more specialized equipment such as a hydration bladder or backpack sprayer, which allow for more herbicide solution to be carried; a hypohatchet, which allow for one hand to remain free; or a line-fill vaccinator, which delivers a precise dose and may be attached to a hydration bladder.

Regardless of the equipment selected, adding a small amount of timber marking dye in the herbicide solution helps the applicator see what has been treated. But note that using too much dye can cause clogging issues with the spray equipment. All equipment should be thoroughly washed after each use and be sure that the chemical residue does not get into the root zone of susceptible plants. Keep hatchets and machetes sharp and lightly oiled to prevent rust. As this application technique is being applied to non-grazable portions of the plant, grazing restrictions/deferment do not apply in direct relation to the herbicide. However, grazing deferral may be necessary for 1-2 growing seasons to ensure adequate grass stand establishment and forage biomass. Grazing deferment will depend on whether prominent forage species are already established or if seeding is needed, the pasture condition, rainfall and the livestock stocking rate. Consult with a grazing specialist for recommendations specific to your site and situation. While herbicide solution moves quickly into the tree when using this technique, do not

apply during rain or when rain is imminent (within one hour) as it may wash away the herbicide. Depending on the type of herbicide used, season and weather, injury can be obvious from weeks to months. Recommended herbicides for this technique include triclopyr, imazapyr and glyphosate. Other herbicides may also work, but these are effective and readily available. The herbicide selected depends on tree species and nontarget injury concerns. Be sure to wear protective clothing and equipment, such as boots, pants, long sleeve shirt, elbow length chemical gloves, a respirator and eye protection.

Triclopyr or Glyphosate: If using triclopyr, the entire tree circumference must be girdled (typically with a chainsaw past the inner bark). Alternatively, you can use a hatchet, but the hack marks must overlap so that the entirety of the tree circumference is severed. Using a hatchet to fully girdle the tree is time-consuming and tiresome – a chainsaw is more effective. If using a chainsaw, make sure the girdle overlaps and use caution to not lean or fall into the blade as you circle the tree. Only use the amine formulation of triclopyr for this technique (look at the chemistry description on the front page of the chemical label for the word amine, or triethylamine salt). Apply a solution with at least 50% herbicide product (if using a product with approximately 44% active ingredient) and 50% water to the entirety of girdle being sure to thoroughly wet the entire girdle. Glyphosate can be used instead of triclopyr using the same tree injury methods. If using glyphosate, apply a solution with at least 50% herbicide product (if using a product with approximately 41% active ingredient) and 50% water. Both herbicides are effective on many tree species. Refer to herbicide labels for specific instructions and woody plants affected. Additionally, both herbicides have minimal soil activity and present low risk of injury to adjacent nontarget trees, making them effective when desirable trees are nearby. However, the requirement of injuring the tree around the entire circumference dramatically increases labor. While the herbicide solution rapidly moves into the tree when using this technique, do not apply during rain or when rain is imminent. Note that while triclopyr and glyphosate are broadly effective on many species of trees, there are exceptions. For example hickory (Cayra species) species are difficult to kill with triclopyr. For forests with a complex species composition, it may be most desirable to mix various herbicides. See mixing instructions below for triclopyr and imazapyr.

Imazapyr: If using imazapyr, make one hack mark with a hatchet or machete for every 3-inch dbh of tree. For example, a 9-inch dbh tree requires three hacks as evenly spaced as possible. Hacks should be at a downward angle (approximately 45 degrees) to form a cup that can hold herbicide solution. For most trees, minimal effort is needed to make this wound, considering you only need to cut through the bark. However, large trees with thick bark require extra effort to penetrate deeply enough to get the herbicide into the tree. Expect lower efficacy on large diameter trees. Take care not to hit the tree at a steep angle, because this can cause the blade to slide down the tree trunk and strike your leg. Wearing safety chaps can help protect the applicator. Note that applying imazapyr is much faster than using triclopyr or glyphosate due to the minimal amount of tree injury required, as described above.

Figure 2. An example of a tree that was girdled with a chainsaw and then the entire girdle was sprayed with a triclopyr solution. Girdling without herbicide can be used in some situations, especially if resprouts are acceptable or unlikely. Note that the girdle is connected around the entire circumference.

Once the wound is created and while the blade is still in the tree, apply about 1 milliliter (usually 1-2 sprays from most spray bottles) of solution with 50-75% herbicide product (if using a product with approximately 28% active ingredient) and 50-25% water. The squirt can either be applied directly into the wound or onto the imbedded blade, allowing it to flow into the wound. Note that the herbicide label specifies 75% herbicide (and 25% water) for this application, but rates as low as 50% have proven highly effective for many tree species including oaks. The recommendations provided here are for the nonrestricted concentration containing approximately 28% active ingredient as listed on the herbicide label. There is a more concentrated version of imazapyr (Applicators Concentrate or AC) that can be purchased if you have an herbicide applicators license. Mixing rates should be adjusted if the AC version is used. Caution should be exercised when using imazapyr as it is soil active - avoid runoff and drift from tree into the soil. Be careful to apply the herbicide solution directly into the wound. Do not overspray to the point that herbicide runs down the bark to the soil.

To minimize runoff, set the nozzle to an intermediate squirt (not stream or spray) and leave the blade in the tree until the herbicide flows into the wound. Setting the nozzle to a tight stream will cause herbicide to splash out of the wound. To minimize herbicide droplets from falling onto the ground or hitting the applicator, make sure that most of the herbicide has flowed from the blade into the wound before removing the blade. If the nozzle is set to spray a fine mist, herbicide solution may aerosolize and fall to the forest floor. Excessive amounts of mist can cause injury or death to nontarget trees. Oaks are particularly vulnerable to imazapyr, and caution must be used to minimize nontarget injury. Imazapyr is slow acting, and you may not see injury until the second growing

season. While imazapyr is broadly effective on many woody plants, it is not at all effective for hackberry/sugarberry (Celtis genus), pine (Pinus genus), and only moderately effective for Elm (Ulmus genus). Imazapyr is also not recommended for treating legume trees (discussed below). Like triclopyr, there is no herbicide that has 100% efficacy on every species. For stands with complex tree species compositions, consider mixing triclopyr and imazapyr. The mixing recommendation is 50% triclopyr amine (if using a product with approximately 44% active ingredient), 20% imazapyr (if using a product with approximately 28% active ingredient) and 30% water. This is a useful mixture to target most woody plants as some are more susceptible to triclopyr, while others are more susceptible to imazapyr. If using this mixture, mix the triclopyr first, then the water and the imazapyr last to keep the mixture from clogging the spray nozzle. Agitate this mixture frequently to keep contents mixed in suspension. Also, note that you will need to use the girdle and squirt method with this mixture.

Cut Stump

Like hack and squirt, cut stump treatment applies herbicide solution to the actively growing portions of an individual tree. As mentioned previously, this area is located inside the bark. Unlike hack and squirt, target trees are not left standing after treatment. This may be preferred in situations where snags are not desired for safety or aesthetic reasons. Although snags are used by many bat and bird species, some wildlife species avoid snags. Cut stump treatment may also be used after a timber harvest to convert the site to an open woodland or to selectively limit which tree species may resprout following cutting. Like the hack and squirt method described above, to increase effectiveness, avoid using this treatment application during the spring green up period when sap is rising in trees (March-early May).

Figure 3. Cut stump treatment requires the entire circumference to be treated. Notice that the heartwood is not sprayed. Marking dye aids in observing where herbicide has been applied (see youtube.com/watch?v=P_LKq8V2bHc).

Protect yourself with boots, pants, long-sleeve shirt, elbow-length chemical gloves, a respirator and eye protection. All equipment should be thoroughly washed after each use. Herbicides for this treatment include triclopyr (either amine or ester) and glyphosate. Place a small amount of timber marking dye in the herbicide solution so the applicator can see the trees that have been treated. As this application technique is being applied to non-grazable portions of the plant, grazing restrictions/deferment do not apply. While the herbicide solution quickly moves into the tree roots when using this technique, do not apply during rain or when rain is imminent (within one hour).

Triclopyr or Glyphosate: Triclopyr is available in either ester or amine formulations. These formulations are not always interchangeable and specific differences in application and mixing exist. But for cut stump, either can be used. If using the ester formulation (look at chemistry description on front page of chemical label for the word ester) of triclopyr, apply a solution with 25% herbicide product (if using a product with approximately 60% active ingredient) and 75% water to the entire circumference inside of the outer bark. If applying this solution within 15 minutes of the tree being cut, water is adequate to mix with the herbicide. However, if the application is delayed beyond 15 minutes, use 75% oil carrier (crop oil or diesel) instead of water with the balance (25%) being triclopyr ester. This allows stumps to be treated long after the stump has sealed. This method is useful following a timber harvest, when it is unsafe or impractical to apply the herbicide during the harvest. If using the amine formulation (look at chemistry description on front page of chemical label for the word amine or triethylamine salt) of triclopyr, apply an undiluted product (if using a product with approximately 44% active ingredient) to the entire tree circumference. If using amine, apply within 15 minutes of felling the tree. If using glyphosate, apply a solution with at least 50% herbicide product (if using a product with approximately 41% active ingredient) and 50% water to the entire circumference within 15 minutes of felling.

Basal Bark

Basal bark is a technique that does not require injuring or cutting the outer bark of a tree. Instead, herbicide slowly penetrates the outer bark and moves into the actively growing portion of the tree where it is translocated throughout the tree. An oil is mixed with the herbicide and acts as a surfactant preventing the herbicide from running down the stem and allowing time for the herbicide solution to penetrate the outer bark. Since the outer bark is not severed, basal bark treatment has more limited application, and efficacy is affected by tree size, bark thickness and to some extent tree species. It is primarily used for smaller diameter (less than 6-inch dbh) thin-barked tree species that are often in the midstory of a forest stand. Since the focus is on removing trees in suppressed or intermediate canopy positions (thinning from below), this technique mimics the self-thinning process. Trees that maintain thinner outer bark even as they mature can be effectively controlled at larger diameters often up to 10-inch dbh. Species such as tree-of-heaven, maple (smaller dbh), locust (smaller dbh), redbud, privet, sweetgum (smaller dbh), willow and ash (smaller dbh) can be readily controlled with this method. Oak can be more difficult to kill with basal bark technique even when small as the bark tends to be thick.

If treating more than a just a few dozen stems, a backpack sprayer will be needed because this method requires a lot of herbicide solution for each tree. Soil active herbicides are not appropriate for basal bark treatment as this treatment can have significant runoff, splash and mist, causing potential nontarget injury. Basal bark treatment is effective at removing scattered midstory trees or young and isolated invasive trees. However, dense stands of pole-sized timber can be cumbersome to treat due to the number of potential trees to remove and the lack of space to navigate through the dense stand. A backpack sprayer gets heavy quickly, especially when moving in tight spaces. A smaller 1-2.5-gallon handheld sprayer is generally easier to use in dense stands. Soil-applied herbicide may be more effective for dense stands. If the stems are sparse and are more than 3-inch dbh, hack and squirt technique can be less laborious. Protect yourself with boots, pants, long-sleeve shirt, elbow-length chemical gloves, a respirator and eye protection. Because this method tends to result in splash on the lower legs, rubber knee boots are recommended. Placing a small amount of timber marking dye in the herbicide solution can be used, but generally the oil from basal bark is readily visible even without the dye. All equipment should be thoroughly washed after each use.

For basal bark treatment, the entirety of the stem circumference must be coated with the herbicide solution. Set the spray nozzle to a moderate spray where no misting or splash occurs. While it is recommended to spray from the base of the stem (at ground level) 12-18 inches and fully coat the entire circumference of the stem, effectiveness is adequate if spraying at breast height in most situations as long as at least 12-inches of the stem is fully coated until the point of runoff. Leaving an unsprayed portion of the stem will injure the tree but not usually kill it. For smaller trees with thin bark, spray until slight runoff, being careful not to oversaturate to the point of ground contact but ensuring the spray begins to run down the stem. However, the total amount of herbicide solution varies with bark thickness. Rougher corky bark, such as oak and hickory, require a heavier application to saturate sufficiently for runoff to get effective efficacy. Spraying collar roots is effective as well, although, you may have to use your boot to push back soil and litter from the roots. Exposing and spraying these roots at the base of the tree can allow for larger trees to be killed. For basal bark treatment, use only the ester formulation (look at chemistry description on front page of chemical label for the word ester) of triclopyr. The recommended solution is 20-30% herbicide product (if using a product with approximately 60% active ingredient) and 80-70% oil. As previously mentioned, the oil acts as a surfactant preventing the herbicide from running down the stem and allowing time for the herbicide solution to penetrate the outer bark. Diesel or kerosene can be used in place of crop oil, which is more expensive. However, diesel and kerosene can damage the seals in most sprayers. Therefore, either

Treating Honey Locust

Honey locust often forms dense thickets and is prone to vigorously resprout along the lateral roots following cutting/felling/prescribed fire. For these reasons, landowners may consider killing isolated honey locust before conducting land clearing or prescribed fire. While triclopyr is somewhat effective and often used to treat honey locust using both basal bark and cut stump methods, efficacy is often unacceptable (less than 80%), and some trees will survive and resprout. The herbicide aminopyralid (approximately 40% active ingredient) has been shown to be more effective for honey locust than triclopyr. This herbicide can be applied through basal bark (5% herbicide product and 95% carrier) or cut stump (10% herbicide product and 90% water).

Note that aminopyralid does not tend to stay in suspension for basal bark application with some oil carriers, therefore seed oils with emulsifiers and nearly constant agitation of the tank are recommended to keep the herbicide from separating. Talk with a herbicide representative or do a jar test to ensure the solution stays in suspension before mixing in the herbicide tank. Also, only mix the amount you intend to use the day of application.

use sprayers with seals capable of withstanding diesel, plan on replacing seals or use crop oil instead. Also, diesel tends to volatize during hot weather, and crop oil may be more stable during the heat of summer. Do not use imazapyr with basal bark treatment because this herbicide is soil active and is likely to injure nontarget trees as the herbicide often runs down onto the soil when applying with this technique. Additionally, glyphosate is not recommended for this technique. Avoid application when bark is saturated with water or during rain. As this application technique is being applied to non-grazable portions of the plant, grazing restrictions/deferment do not apply for cattle. However, if goats have access to treated trees, deferment should be considered, particularly during the winter when goats are likely to strip bark from thin-barked species. Always check the specific herbicide label for any restrictions. Also, it is recommended to only mix what herbicide is needed for one day and agitate frequently to keep the herbicide and carrier in suspension.

Special application: An additional use for basal bark treatment is in situations where non-desirable trees need to be suppressed (but not necessarily killed) to reduce competition for adjacent desirable trees. This can be useful for suppressing codominant trees in a young forest stand. For example, if trying to favor slower growing oaks over fast growing sweetgum, the sweetgum can be sprayed on the side facing the oak. This will injure but not typically kill the sweetgum. However, the side that is sprayed will lose limbs and leaves, and slow growth. This allows additional sunlight and space for the oak to grow until it can overtop the adjacent tree. This may also help oaks (or other desirable trees) reach a dominant canopy position without putting an excessive amount of sunlight on the tree, which can cause excessive epicormic (along the stem) sprouts. Even large trees with thick bark can be temporarily injured (and often killed) in this way. This specific application can be applied when attempting to change stand composition over a longer period for various reasons, including production of hard mast (e.g., oak) or more valuable timber (TSI application). Note that while this is not a herbicide-labeled recommendation, it has been shown to be effective for some goals. However, if the intent is to fully kill a tree, the label recommendations should be followed.

Figure 4. Basal bark application is generally used on smaller trees with thin bark. These honey locusts are slightly larger than recommended for basal bark treatment. Efficacy of this treatment was less than desired.

Soil Applied Herbicides

There are several herbicides that can be applied via solid pellets or liquid form directly to the soil around target trees. The herbicides tebuthiuron and hexazinone are the more commonly used soil-applied herbicides. These herbicides are taken up by the roots from the soil. A benefit of using solid pellets is the ease of application. They can be applied from the air, from a handheld spreader, an ATV spreader or by hand (using chemical gloves) to targeted plants. There are no mixing requirements or messy liquids, and they are easy to transport. Weight is also reduced since the applicator is not using a liquid carrier. However, there are several considerations for using soil-applied herbicides. First, there is high variability in efficacy. Efficacy can vary dramatically depending on soil type, slope, bedrock, precipitation, time of year and species of tree. Recommended label rates reflect this and are broad. This makes it difficult for the applicator to anticipate overall efficacy. For these reasons, it can be difficult to achieve some prescriptions, especially when a narrow range of final canopy cover is desired. Applicators sometimes err on the side of caution yet may have to reapply to meet the prescription or, risk overshooting the canopy removal target. Also, the recommended rate of application per acre can vary between various tree species, presenting another challenge in stands with a diverse species composition. Therefore, depending on stand composition and target species, carefully review the label recommendations.

While soil-applied herbicides can be directly applied under the canopy of targeted trees, once in the soil the herbicide can move, injuring nontarget plants. The root zone of a tree can extend a great distance from the base, sometimes twice the distance of the crown (drip zone). Although the applicator can attempt to minimize nontarget injury, there is some risk to adjacent desirable trees. In a complex forest of various size classes, ages and species compositions, it may be more desirable to use other FSI techniques, especially when minimal canopy removal is

desired or when highly desired trees are present. Despite these limitations, if the goal is to remove most of the overstory, this method is quick and efficient. For example, converting a closed canopy forest to a savanna for bobwhite and/or livestock grazing. Additionally, in some upland oak forests that have an even age class distribution, uniform composition and structure and a high-stem density, soil-applied herbicides will be much quicker than the single-tree application methods described above. Applicators should carefully evaluate the tree canopy of the area to be treated and consider the target canopy cover objective. A resource professional can assist with this. As this method of herbicide application often results in complete kill within the area that the herbicide is directly applied, the applicator will likely need to treat only parts of the treatment area and create pockets of openings in the canopy. To protect

A Forest Thinning Example using Tebuthiuron:

A landowner has an oak dominated stand that is 10 acres where the canopy cover is 80%. The objective is to reduce the canopy to 40%.

To calculate the treatment area to achieve objective use the following formula:

- [(Baseline Canopy * forested acres) - (Desired Canopy * forested acres)] / Baseline Canopy

For this example:

- [(80% * 10 acres) - (40% * 10 acres)] / 80% = 5 acres to be treated

A handheld spreader may be used to distribute the herbicide for smaller scale projects such as this. The applicator will need to determine the distance the herbicide spreader will distribute the herbicide to calculate the minimum treatment area.

Based on the stand composition, a rate of 10 pounds per acre (equates to 0.0037 ounces per square foot) is prescribed.Assume for this example, the handheld spreader throws the herbicide 15 feet (an area of 707 square feet); this would equate to 2.6 ounces of herbicide per 15-foot circle. Note: Even small changes in the radius drastically change the application rate. Careful calculations will mitigate against over application, saving money and reducing injury to non-target plants. For example, a 10-foot radius circle uses 1.2 ounces, whereas a 20-foot radius circle uses 4.6 ounces.

It is good practice to add a buffer of twice the distance to account for roots that extend under the treated soil. Therefore, the total impacted area is assumed to be a 30-foot radius—an area of 0.065 acres. Note: Even small changes in the radius exponentially change the number of treatment plots. Careful calculations will mitigate against over application. For example, doubling a 10-foot radius circle to 20 feet equates to 0.029 acres impacted, whereas doubling a 20-foot radius circle to 40 feet equates to 0.115 acres impacted.

Since in this example we want to treat 5 acres and the treatment plots (i.e., impacted area) are 0.065 acres each, the applicator will need to treat about 77 plots (5 acres / 0.065 acres). Using 2.6 ounces of tebuthiuron at each point equates to 12.5 pounds (2.6 ounces * 77 points / 16 ounces in a pound) of total herbicide needed to treat the stand.

A clicker and map/GPS unit is helpful to keep track of treatment points to ensure they are evenly distributed and not overlapping. Note: If treating points, evenly distribute the herbicide by spreading twice in opposite directions or spinning at the center point.

Alternatively, parallel transects could be walked throughout the stand. For this example, the distance between the transects would be about 120 feet (twice the distance of the estimated kill) to remove 50% of the canopy. The amount of herbicide needed would be the same (12.5 pounds); however, it can be tricky to calibrate the correct rate as it requires a near constant walking speed. Using a UTV mounted spreader may be preferable in some forest stands as the spreader can be calibrated and a constant speed driven.

It is obvious from the above example that this is not precise as we cannot know for certain how far the roots extend from trees. Nevertheless, this prescription should result in a range of 40-60% final canopy for this example. Always err on the side of underapplication if a lower canopy cover would be unacceptable. A second application can be used to home in on your target canopy cover and desired look of the stand.

yourself during application, wear boots, pants, long-sleeve shirt, elbow-length chemical gloves, a respirator, and eye protection. There can be significant dust with this method, so a respirator and eye protection are necessary. Note that it may take several months to see the full effect of this herbicide. For example, if applied during the summer of year one, the trees will often leaf out in the spring of year two before slowly showing severe injury and death during that growing season. Do not assume the treatment was ineffective until giving ample time to see the full results.

Tebuthiuron (20% active ingredient in pellet form): If using solid pellets of tebuthiuron with 20% active ingredient, rates as low as 2.5 pounds per acre are recommended for sandy soils and when only partial control of woody plants is desired. Rates as high as 20 pounds per acre may be needed for some hard-to-kill woody plants such as hickory. Rates of 10 pounds per acre are typically adequate for thinning oak forests; this rate equates to 2.5 ounces per 15-foot radius plot – which is approximately the radius treated with many hand spreaders. If using another delivery method or concentration of tebuthiuron besides 20% active ingredient, adjust rates accordingly. Similarly, adjust the rate if your spreader throws shorter or farther than 15 feet (see sidebar). Do not use tebuthiuron on heavy clay soils (greater than 30% clay) that crack when dry. On shallow sandy soils, apply lower rates, while deep sands will require higher rates. There are no grazing restrictions related to the herbicide after application of tebuthiuron (solid pellets), but haying should be deferred for one year to prevent transfer of herbicide in plant material to other sites. However, if seeding is conducted after the tree thinning, deferring grazing two growing seasons is recommended to ensure adequate grass stand establishment. In sites that are not seeded, and natural plant succession is adequate, grazing can commence as soon as the grass is established, and forage biomass is determined to be sufficient by a grazing specialist. Herbicide efficacy is improved when trees are healthy. As prescribed fire can cause injury or stress to trees, the tebuthiuron herbicide label recommends fire be deferred for two years following herbicide application. However, this delay may not be necessary in all situations. If trees are clearly dead or dying after one growing season and the objective has been meet from the herbicide application, there would be no reason to further delay application of fire. Also, low intensity fires that are unlikely to injury or stress overstory trees could potentially be used prior to the end of the two-year recommended deferment period. Nevertheless, use caution not to stress or injure trees while the herbicide is taking effect. Because of this recommended fire deferment period, it may be helpful to conduct a dormant season prescribed fire prior to herbicide application to clear the litter layer and eliminate redcedar seedlings that will quickly respond once the overstory is opened by the herbicide. Tebuthiuron can be applied at any time of year. However, potential injury to native warm-season grasses and forbs can be minimized if application occurs November – March.

Hexazinone: Hexazinone can be applied as a pelleted or liquid formulation and is an effective redcedar control option that does not require a chemical applicators license. This herbicide can be applied anytime the soil is not saturated or frozen but will kill the tree the quickest if it is actively growing and .25 -.5 inches of rain are expected within the next two weeks. In Oklahoma, early spring- summer is typically best. Do not apply hexazinone for 3-6 months after a prescribed or wildfire or where the water table is shallow. Similar considerations as provided for tebuthiuron are applicable in that tress should not be stressed by fire until the herbicide has had time to kill them. Wait to burn skeletons after the tree is completely defoliated; do not burn after brown down. Both forms of hexazinone are non-selective and can harm many species of woody and herbaceous plants. In addition, they are only labeled for individual plant treatments, can be labor intensive and leave tree skeletons intact. The rate of application should be based on the original tree size, not the small regrowth from resprouting trees. Hexazinone can be a good option when cedar and hardwoods will both be treated and when cedar is on steep slopes or shallow soils. Moreover, it is safer and less laborious than felling or hack-and-squirt.

NOTES ON HERBICIDE TRANSLOCATION BETWEEN TREES

There may be situations where adjacent trees (particularly of the same species and species that are clonal) are root grafted to each other, facilitating movement of herbicide between trees. While movement of herbicide between grafted/clonal trees is certainly possible and is frequently cautioned in various herbicide labels and herbicide technical documents, many applicators indicate they rarely observe it happening in treated stands. Despite these observations, consideration should be given if there are particularly valuable trees immediately adjacent to treated trees. An additional concern is that legumes (e.g. redbud, honey locust, black locust, mesquite, etc) can move herbicide into the soil from their roots. This is one reason that imazapyr (which is soil active) is not recommended for treating legumes. Imazapyr is also less effective than triclopyr for legumes. This can be problematic in situations where large stands of dense legumes (e.g. locust or mesquite) occur with desirable trees (e.g. pecan, hackberry, elm) mixed in the stand. For these situations, there are specialty herbicide mixes that offer selectivity targeting locust or mesquite (foliar) and minimize injury to other desired tree species. Visit with your local herbicide salesperson to discuss options.

Liquid hexazinone is less expensive than the pelleted version but can be messy. An applicator gun that attaches directly to the herbicide container is often sold at retailers who sell this product. Similar to the pelleted version, spring or summer application is preferred. Apply liquid hexazinone undiluted without a surfactant at a rate of 2-4 milliliters per inch stem dbh to the soil below the canopy. For larger trees that require more than one dose, space each evenly around the tree. For coarser soils, like sand and sandy loams, the lower rate should be used while the higher rate should be used for finer textured clay loams and clays. You should not exceed 4 gallons of liquid hexazinone per acre per year. Liquid formulations have no grazing restrictions but do have hay restrictions up to a maximum of 60 days if applying as a foliar application. There are no haying restrictions for basal soil treatments.

The pelleted version of hexazinone (75% active ingredient) is convenient to apply and requires no mixing; simply put 1-2 pellets per inch of stem dbh below the tree canopy. At rates greater than 5,000 pellets per acre, do not hay or graze treated areas for one year. At rates of 600–5,000 pellets per acre do not hay or graze for 60 days. At rates less than 600 pellets per acre, there are haying or grazing restrictions. However, if seeding is conducted after the tree thinning, waiting for two growing seasons is recommended to ensure adequate grass stand establishment. In sites that are not seeded, and natural plant succession is adequate, grazing can commence as soon as the grass is established and forage biomass is determined to be sufficient by a grazing specialist.

FSI Mechanical Techniques

Felling

Felling a tree consists of cutting the stem at or near the ground level. This can be done with a chainsaw, axe, hand saw or some type of cutting/shearing/pinching device mounted on a wheeled or tracked vehicle. Using a vehicle mounted felling device is often used because it may be safer, faster and can cut large trees. However, some situations do not allow for vehicles to be used effectively. For example, in dense forests where redcedar are scattered throughout the stand, vehicle entry and movement may be limited, necessitating the use of hand-operated saws. When felling by hand, the operator should carefully determine which direction the tree can be safely felled. A notch (wedge) is then cut out of the tree on the side that the tree is intended to fall towards. Then the operator cuts toward the notch from the opposite side of the tree so that the cut is slightly above the notch. This results in the tree falling toward the notch direction.

Figure 5. Felling resprouting trees, such as this American elm, can provide additional forage, cover and change overstory composition. Note that the stump sprouts have been heavily browsed by deer. This tree was cut during the dormant season.

It is recommended to have another person (spotter) with the operator for safety considerations. Regardless of the method, felling results in death of the tree for species that do not resprout. However, most woody plant species in Oklahoma are vigorous resprouters. If the objective is to create a dense shrub layer in the forest understory, felling may be the prescription of choice. Frequent fire (every 2-4 years) can then be used to keep the sprouts at the desired height. However, when the objective is to kill the plant (e.g., invasive plants, increasing livestock forage or having an open understory) herbicide should generally be used rather than relying on felling alone. Redcedar is an exception and will not survive if it is cut below the lowest living limb. However, completely felling a redcedar by hand can be risky and difficult due to a center of gravity close to the ground. This often makes it difficult to determine which direction they will fall unless the tree has a significant lean. Further, chainsaw bars sometimes become pinched by the tree if it does not start tipping in a certain direction and redcedar trees often hang in the canopy of adjacent trees. Therefore, girdling may be a safter option for a hand operated chainsaw for straight redcedar trees larger than 6-inch dbh. Whether girdling or felling, it is often necessary to limb the redcedar because they do not self-prune. When felling trees, protect yourself with boots, pants, long-sleeve shirt, leather gloves, a hard hat, chainsaw chaps and eye protection at a minimum.

As mentioned, many resprouting trees will vigorously resprout after felling. Yet, there is a relationship between time of year and size/age of the tree that determines probability of resprouting. Dormant season felling has a high probability of causing resprouting, while early growing season felling (May-July) has a higher probability of causing tree mortality. This varies between species but the difference between dormant and growing resprouting can be 3x lower. Additionally, trees less than 6-inch dbh have a high probability of resprouting and trees greater than 12-inch dbh have a lower probability of resprouting. Therefore, in situations where resprouting is not desired, felling larger trees during the early summer may result in higher (but not absolute) tree mortality. Survival of larger, older trees cut/girdled during early summer can less than 30% in some cases. Conversely, felling trees during the winter (especially young trees) generally results in abundant root sprouting - often greater than 90% survival.

Girdling

Girdling can also be used to top-kill trees. Other terms used for this technique include notching, ringing and peeling. While some sources distinguish between these terms based on the depth of the injury, the width of the injury and even the way that it is administered, in this document we use the term girdling to mean any injury that completely severs the vascular cambium around the entire circumference of the tree but leaves the tree standing (i.e., not felling) and does not use herbicide.

If the intent is to kill the tree, girdles must completely encircle the tree and connect. Cut past the bark so the cambium is severed. Shallow girdles may not cause mortality. Two parallel girdles work better than one. A zipper method may be used, whereby the operator girdles twice (two parallel girdles), cuts a horizontal path to connect the girdles and then uses a hatchet to peel off the inner and outer bark in one piece. While this ensures tree mortality, it takes longer, so it should only be used if there are few target trees. When girdling redcedar, one deep girdle is generally sufficient but works best when done during the summer. It is often necessary to trim lower limbs from redcedar first, so the operator can move around the stem. Girdling may also result in wind-thrown redcedar during high winds, so exercise caution. Redcedar is highly rot resistant and stems may persist for many years after the tree is killed. If this is not desired, mulching or burning may be used to consume the tree skeletons. To protect yourself when girdling trees, wear boots, pants, long-sleeve shirt, leather gloves, a hard hat, chainsaw chaps and eye protection at a minimum.

Figure 6. Girdling without herbicide can be useful, particularly with non-resprouting woody plants such as eastern redcedar. Note that the lower limbs were removed prior to girdling, and the operator is wearing the appropriate safety clothing.

Hinge Cutting

Hinge cutting involves partially cutting a tree 3-4 feet off the ground, so the part above the cut falls over but remains connected to the standing part below the cut. As soon as the tree starts to fall over, stop cutting and move away from the direction the tree is falling. The objective is to put most of the tree on the ground without completely severing it from the roots. This should only be attempted on trees less than 8-inch dbh for safety considerations. These trees are often suppressed in the midstory, so this is a type of thinning from below. Larger trees pose a risk to the applicator due to kickback and often hang in the adjacent tree canopy. For these reasons, some professionals do not recommend hinge cutting, and it is not appropriate in all stands. Judiciously choose trees to hinge that are leaning, will fall in a predictable way, are smaller and are not likely to hang in adjacent tree canopies This practice should only be applied when at least two people are present for safety considerations. Despite the limitations, hinge cutting produces immediate cover that can be used by loafing deer, nesting wild turkey and roosting woodcock. Hinging several trees in proximity can provide dense security cover for deer and rabbits. Additionally, trees such as elm and hackberry that are preferred browse are sometimes hinged to provide additional deer and cattle food resources. Hinged trees can stay alive for multiple years, especially when hinged during the dormant season. Not only is the top of the tree made available as forage, also root sprouts often form, providing forage for many years. To protect yourself when hinge cutting trees, wear boots, pants, long-sleeve shirt, leather gloves, a hard hat, chainsaw chaps and eye protection at a minimum.

Figure 7. Hinge cutting involves leaving the cut stem partially attached to the root of the tree. This should only be attempted on small trees that will not hang in the adjacent tree canopy. This hackberry will now provide deer forage and cover (see youtube.com/watch?v=Y9ki-hTiW7o).

Figure 8. Eastern redcedar often grow in dense stands. Hinging trees on the outer perimeter of these stands creates a ladder fuel that can enable prescribed fire to be more effective at killing the remaining trees. Care must be taken if using this approach as it results in hung trees and can create volatile fire conditions. Consult with a professional and be selective where this technique is applied.

Mastication

Mastication, or forestry mulching, is sometimes prescribed as an efficient way to quickly remove woody biomass and open up both the midstory and overstory. A masticating (wood chipping) head mounted on the front of a vehicle can quickly turn small diameter, standing woody vegetation into mulch.

Figure 9. Mastication is a quick way to remove forest overstory and create open woodlands. However, oak readily resprouts as can be seen in this image. Frequent fire or herbicide application may be needed if the goal is to maintain an open forest structure.

Mastication can be used for sprouting woody plants when resprouts are not a concern. Dormant season (winter) mastication will result in abundant resprouts, while summer mastication may cause some tree mortality depending on the size of the trees masticated.

If masticating smaller diameter trees, expect most to resprout regardless of season. Mastication is a highly effective control for non-resprouting woody species like redcedar. It has the added benefit of removing the skeletons, which can persist for many years following fire, herbicide or girdling treatments. However, mastication is typically more expensive than cutting cedars with a tree shear or saw. An additional consideration is the remaining mulch can be a concern when planning future prescribed fires. Wet mulch can prevent the fire from spreading well across the burn unit, yet dry mulch will typically burn longer than herbaceous grass or broadleaf fuels. Mulch can carry fires across firebreaks presenting escape risks. For this reason, the mulch should be pushed back into the burn unit to prevent fire escape. Also, dense mulch that is piled at the base of retained trees can damage the tree due to the long time that it burns. Therefore, mulch should be raked back about 3 feet from the stem base if a tree is highly valued. If grass seeding is conducted after mastication, waiting for two growing seasons before grazing is recommended to ensure adequate grass stand establishment. In sites that are not seeded and natural plant succession is adequate, grazing can commence as soon as the grass is established and forage biomass is determined to be sufficient by a grazing specialist.

Summary

FSI is a broad term that includes any practice intended to improve a forest stand for various goals. FSI may be used to improve habitat for wildlife species, to increase forage resources for livestock, to reduce volatile fire risk and to increase the aesthetics of an area. In areas where wood products may be commercially viable, the same practices (TSI) are used to increase the value of a forest stand for future timber harvests. Depending on the landowner goals, the stand condition and available resources, various herbicide and mechanical methods may be used. There are professionals that can assist landowners with the safe and effective application of these methods. Additionally, these professionals can provide guidance for practices that are not covered in this document, such as foliar applied herbicides, understory vegetation management, prescribed fire and grazing. Potential contacts to assist include private lands biologists with the Oklahoma Department of Wildlife Conservation, foresters with the Oklahoma Forestry Services, local Natural Resource Conservation Service offices, private consulting foresters, biologists with private conservation groups (e.g., Quail Forever, National Wild Turkey Federation) or local Cooperative Extension offices.

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Resources

Technical Assistance & Videos

Oklahoma Department of Wildlife Conservation (ODWC) Landowner Programs. https://www.wildlifedepartment.com/lands-and-minerals/landowner-programs

Oklahoma Forestry Services. https://ag.ok.gov/ofs-directory/

Pheasants Forever Inc. and Quail Forever Biologists (partners with ODWC, OPJV, NRCS). https://pheasantsforever.org/Habitat/findBiologist.aspx

USDA Natural Resources Conservation Service (NRCS) Local Service Centers Directory: https://www.nrcs.usda.gov/contact/find-a-service-center?state=40&county=

Naturally Speaking - Managing trees & deer (11/17/18) - YouTube. https://www.youtube.com/watch?v=P_LKq8V2bHc

Naturally Speaking (11/18/17) - YouTube. https://www.youtube.com/watch?v=Y9ki-hTiW7o

Plant Identification

Apps: iNaturalist, PictureThis, PlantNet

Forest Trees of Oklahoma (Oklahoma Forestry Services). https://ag.ok.gov/product/forest-trees-of-oklahoma-book/

Field Guide to Oklahoma Plants (OSU Extension.) https://secure.touchnet.com/C20271_ustores/web/product_detail.jsp?PRODUCTID=1076

Trees, Vines, and Woody Vines: a Pictorial Guide (Noble Foundation). https://www.noble.org/educational-publications/

Commonly Used Herbicides

Herbicide[1] (% Active Ingredient)	Method of Application[2]	Mixing	Season of Use	Notes[3]
Aminopyralid (41%)	cut stump	10% herbicide/90% water	anytime not raining	broad spectrum; highly effective on locust
Aminopyralid (41%)	basal bark	5% herbicide/95% oil	anytime that bark is not water saturated	broad spectrum; highly effective on locust
Glyphosate (41%)	cut stump	50% herbicide/50% water	anytime but spring green up and when not raining	broad spectrum
Glyphosate (41%)	girdle/squirt	50% herbicide/50% water	anytime but spring green up and when not raining	broad spectrum
Hexazinone pellet (75%)	soil	NA	anytime soil is not frozen or saturated, but best in spring or early summer	broad spectrum; effective on redcedar; soil active
Hexazinone liquid	soil	undiluted	anytime soil is not frozen or saturated, but best in spring or early summer	broad spectrum; effective on redcedar; soil active
Imazapyr (28%)	hack/squirt	50% imazapyr/50% water	anytime but spring green up and when not raining	broad spectrum; not effective on hackberry/sugarberry, legumes, redcedar or pines; soil active
Imazapyr (28%) + Triclopyr (60%)	girdle/squirt	20% imazapyr/50% triclopyr/30% water	anytime but spring green up and when not raining	broad spectrum; covers most species
Tebuthiuron pellet (20%)	soil	NA	anytime but best in spring and early summer	broad spectrum; soil active; not effective on large redcedar
Triclopyr ester (60%)	cut stump	25% herbicide/75% water or oil	anytime but spring green up and when not raining	broad spectrum; not highly effective on hickory
Triclopyr ester (60%)	basal bark	20% herbicide/75% oil	anytime that bark is not water saturated	broad spectrum; not highly effective on hickory; not effective on redcedar
Triclopyr amine (44%)	cut stump	undiluted	anytime but spring green up and when not raining	broad spectrum; not highly effective on hickory
Triclopyr amine (44%)	girdle/squirt	50% herbicide/50% water	anytime but spring green up and when not raining	broad spectrum; not highly effective on hickory
Picloram (5%) + 2,4-D (21%)	cut stump, girdle/squirt	undiluted	anytime but spring green up and when not raining	broad spectrum; soil active

Summary of commonly used herbicides for forest stand improvement, application methods, mixing instructions, season of use considerations and special notes on species affected .

1 This is not an exhaustive list of all applicable herbicides. Rather, these are some of the more commonly used and available herbicides in our area. Further, no product names or brands are represented as there are multiple options available.

2 Other methods of application may be possible with each of these herbicides. We present only the relevant and recommended application types for FSI treatments covered in this document. For example, foliar applications are not covered here. While foliar applications are often used in the understory of forests, there are some commercial overstory foliar applications as well.

3 Broad spectrum indicates that many species are affected. Refer to the product label for list of species that are susceptible to the herbicide product. Note that not all affected species are listed on the herbicide labels, as some have not been evaluated.

Notes

Notes

Notes

The Oklahoma Cooperative Extension Service
Extension Everywhere for Everyone

The Cooperative Extension Service is the largest, most successful informal educational organization in the world. It is a nationwide system funded and guided by a partnership of federal, state, and local governments that delivers information to help people help themselves through the land-grant university system.

Extension carries out programs in the broad categories of agriculture, natural resources and environment; family and consumer sciences; 4-H and other youth; and community resource development. Extension staff members live and work among the people they serve to help stimulate and educate Americans to plan ahead and cope with their problems.

Some characteristics of the Cooperative Extension system are:

- The federal, state, and local governments cooperatively share in its financial support and program direction.
- It is administered by the land-grant university as designated by the state legislature through an Extension director.
- Extension programs are nonpolitical, objective, and research-based information.
- It provides practical, problem-oriented education for people of all ages. It is designated to take the knowledge of the university to those persons who do not or cannot participate in the formal classroom instruction of the university.
- It utilizes research from university, government, and other sources to help people make their own decisions.
- More than a million volunteers help multiply the impact of the Extension professional staff.
- It dispenses no funds to the public.
- It is not a regulatory agency, but it does inform people of regulations and of their options in meeting them.
- Local programs are developed and carried out in full recognition of national problems and goals.
- The Extension staff educates people through personal contacts, meetings, demonstrations, and the mass media.
- Extension has the built-in flexibility to adjust its programs and subject matter to meet new needs. Activities shift from year to year as citizen groups and Extension workers close to the problems advise changes.

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