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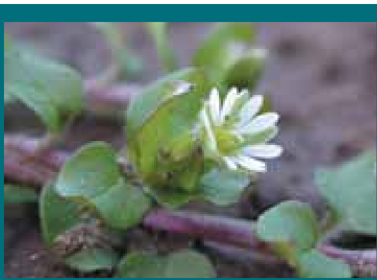

Weed Control in Nursery Field Production

J. Altland

Weeds reduce the value of nursery crops. They compete with crops for nutrients, light, and water. Some vine weeds climb nursery crops, requiring excessive labor for hand removal. Most serious are perennial weeds, which can be harvested with nursery crops and infest the field or landscape where they are subsequently planted. For these reasons, effective weed control is important for producing high-quality, marketable crops.

This publication describes how to develop a weed management program in three phases: field preparation, weed prevention, and management of escaped weeds.

Phase I: Field preparation

Field preparation begins several weeks prior to planting the nursery crop. Use the following steps to prepare the field for planting.

1. Kill existing weeds with glyphosate.
2. Allow 1 to 2 weeks for the weeds to die, and then disk or till them into the soil.
3. Wait another 2 to 3 weeks to allow for new weed germination. This waiting period is a good time to apply preplant fertilizer and soil amendments.
4. Before weeds grow more than 1 to 2 inches, disk or till the field again to kill germinated weeds and prepare the soil for planting (Figure 1).
5. Plant the crop into weed-free soil.

Whether plowing, disking, or rototilling, till only as much as necessary to adequately prepare the soil for planting. Excessive tillage damages soil health. It can accelerate organic matter breakdown, reduce soil aggregates, increase the potential for soil compaction, reduce

Figure 1. The tractor on the left is tilling the field to prepare for planting, while the tractor and crew on the right are planting trees. This method provides a weed-free soil immediately after planting for preemergence herbicide applications.

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water percolation, and reduce soil oxygen levels.

Repeated tillage has few short-term benefits for weed management. Some perennial weeds can be eradicated from fields with repeated tillage over a 1- to 2-year period (tillage every 3 weeks). However, eliminating perennial weeds during the short field preparation process is unlikely.

Repeated tillage does slowly reduce weed seed populations. However, most soils have an abundant depository of seeds, called the seed bank, and its depletion is a slow process (Grundy and Jones, 2002). Excessive tillage during the short period of field preparation (4 to 6 weeks) will not reduce weed seed numbers enough to justify the tractor fuel, time, and potential damage to soil structure. Furthermore, the planting process likely will bring buried seed up to the soil surface, thus partially negating any seed depletion benefits.

Ideally, you should plant immediately after final tillage. Recently tilled fields are free of weeds for a few days, creating an ideal situation for applying preemergence herbicides. Coordinate the final tillage, planting, and first application of preemergence herbicide so that they all occur within a 3- to 5-day period.

Phase II: Prevent new weed establishment

Apply the greatest amount of effort to preventive weed control. Abundant water, fertilizers, and a relative lack of plant competition in newly planted fields make an ideal environment for weed germination (Figure 2). You must take steps immediately to prevent new weed emergence. The most effective preventive weed management program combines sanitation, strict management of cultural practices, and effective use of herbicides or mulches.

Figure 2. Irrigation, fertilization, and wide spacing in newly planted fields provide an ideal environment for weed growth.

Sanitation

Weeds in noncrop areas

Weeds growing along the edges of fields can contribute seed and vegetative propagules (plant parts that can generate new plants) to nearby areas planted to nursery stock. Most weeds reproduce by seed, which can be disseminated to nearby crop areas. Some perennial weeds also spread via roots, rhizomes, or underground storage tissues.

Control weeds along roadways and drainage ditches to reduce infestations. It is preferable to maintain some type of vegetation on noncrop areas to reduce soil erosion; however, these areas must be maintained weed-free.

Maintain drainage ditches with vigorous turf and mow them regularly. Hard fescues are low-maintenance turfs that grow slowly when not irrigated. They form a dense turf that inhibits weed growth. You also might apply herbicides to these areas to control weeds that tolerate mowing. Dandelion (*Taraxacum officinale*), for example, forms prostrate rosettes that evade mowing and subsequently produce wind-blown seed that infests nursery fields.

Highly compacted gravel is an ideal road surface where field layout is consistent from year to year. Gravel roads are preferable to dirt roads because they are less damaging to equipment, produce less dust during the summer, and are not as prone to weed infestations.

Controlling wind-blown seed

Weeds may not be properly controlled on neighboring properties. Some of these weeds produce seed capable of being carried great distances by the wind. Many plants in the

Asteraceae (sunflower) family produce seeds with bristly hairs called *pappi* (singular: pappus). Common groundsel (*Senecio vulgaris*) is a common weed in nursery crops from the sunflower family. Several species in the genus *Epilobium* produce seed attached to a similar tuft of hairs (Figure 3).

Screens or physical barriers at least 6 feet tall will help block wind-blown seed from entering production areas. Nurseries often use pyramidal evergreen shrubs such as arborvitae (*Thuja occidentalis*) for screening production areas from weed seed and herbicide drift. Because most seed blow-in occurs during the growing season, broad, fast-growing deciduous shrubs also can be used.

Tillage equipment

Some weed root systems or underground storage structures are capable of regenerating new plants. For example, yellow nutsedge (*Cyperus esculentus*) produces tubers, and wild garlic (*Allium vineale*) produces underground bulblets. Tillage equipment distributes root fragments or propagules throughout the field, often turning a small weed patch into a widespread infestation.

Identify weeds in areas soon to be cultivated and note whether any have the potential for spreading by severed root pieces and/or propagules. If these species are present, flag the area so machinery operators do not distribute the plant. Kill the weed by spot spraying (Table 2, page 12), then leave that area of the field flagged for

Figure 3.—Seeds of northern willowherb (family Onagraceae) and many other weeds in the family Asteraceae are wind dispersed.

at least 90 days to be sure there is no regrowth from plant parts that escaped removal efforts.

When moving tillage equipment to a different field, clean it thoroughly with high-pressure water or compressed air to prevent the spread of vegetative propagules to non-infested fields.

The most notable weeds in Oregon nurseries that can be spread by tillage equipment include Canada thistle (*Cirsium arvense*), yellow nutsedge, field bindweed (*Convolvulus arvensis*), horsetail (*Equisetum arvense*), quackgrass (*Elytrigia repens*), and wild garlic (Figures 4a–4e).

Cultural practices

Irrigation

Drip irrigation is preferable to overhead irrigation (Figure 5, page 4). Drip irrigation provides water directly to nursery crop roots. The areas between rows remain dry and less conducive to weed seed germination compared to

Figure 4a. Canada thistle.

Figure 4b. Yellow nutsedge.

Figure 4c. Field bindweed.

Figure 4d. Horsetail.

Figure 4e. Wild garlic.

fields with overhead irrigation. Reduced weed seed germination leads to improved herbicide efficacy and longevity and/or reduced need for tillage.

Growers who have switched to drip irrigation also have reported improved crop growth, improved crop uniformity, reduced water usage, and reduced labor costs.

Fertilization

Fertilizer placement affects seed germination and growth. Most plants are adapted to environments of either high or low nutrient availability, not both. Agricultural weeds are at one end of this adaptive continuum; they generally outcompete crops in high-nutrient environments but compete poorly in low-nutrient environments (Liebman et al., 2001). Thus, fertilizer placement in bands among the nursery crop will reduce weed growth compared to broadcast applications.

A common misconception is that placing fertilizers in a band will adversely affect root growth of nursery crops. Crop roots spread out uniformly in all directions even when nutrients are applied in a localized region. Crop roots explore a much larger soil volume in order to anchor the developing plant and seek water.

Many field nurseries place drip tape several inches beneath the soil surface prior to planting. Crops can be fertilized through the drip tape. This method of fertilization is efficient and inexpensive, and it requires less labor compared to applying dry fertilizer to the soil surface with mechanical equipment. Also, nutrients can

Figure 5. Overhead irrigation increases weed growth compared to drip irrigation.

Figure 6. Cultivation between rows has many short-term benefits, but can have long-term negative consequences.

be efficiently applied to crops in small amounts throughout the growing season.

When fertilizing through drip tape, turn the water off just before capillary flow brings the water to the soil surface. If water does not reach the soil surface, neither do nutrients dissolved in the irrigation water. This will reduce weed growth, compared to broadcast or band-applied fertilizers, by limiting nutrient levels on the soil surface.

Cultivation

Tilling and disking between rows for weed control is common (Figure 6). A band of preemergence herbicide is applied within the crop row for preventive weed control, while periodic cultivation is used between rows to destroy recently germinated weeds.

Cultivation results in less herbicide use. For nurseries using overhead irrigation, repeated cultivation keeps the soil surface from crusting, which in the *short-term* improves water percolation. Cultivation also provides a neat appearance.

While repeated cultivation provides excellent weed control between rows, it often has undesirable consequences within the tree row. Many cultivators use a shielding mechanism to keep soil from spilling onto the herbicide band within the tree row. However, many shielding devices are inadequate, allowing soil to be thrown onto the preemergence herbicide barrier. Weeds germinate in the soil on top of the herbicide band, causing the preemergence herbicide to seem ineffective.

Repeated cultivation may have *long-term* consequences for soil structure. Repeated cultivation decreases soil organic matter and deteriorates soil aggregates. Ultimately, soil compaction increases, water percolation decreases, and crop growth is reduced.

Some nurseries have explored the possibility of using living mulches, which are secondary crops planted between nursery rows. Examples of living mulches include clover and grass. In other cropping systems, living mulches increase soil organic matter, reduce compaction from farm equipment, increase water percolation, increase soil aggregates, stabilize soil, and reduce erosion (Figure 7).

To be successful for nursery production, living mulches should require little additional management, should not compete with the nursery crop, and should not attract pests. Candidates include dwarf grasses such as perennial ryegrass, fine fescue, hard fescue, or sheep fescue. When using these crops between rows, apply nitrogen fertilizers in bands within the crop rows, away from the grasses.

Living mulches are used successfully in many field nurseries during the fall and winter. Often, annual ryegrass or barley is seeded between rows in the fall; it grows throughout the winter and is tilled under in spring.

Use of cover crops throughout the summer growing season is rare, primarily due to concerns about competition with the nursery crop. Nursery producers are encouraged to develop a system that allows the use of living mulches throughout the summer growing season.

Herbicide use

For instructions on how to use herbicides safely, consult your local Extension agent or refer to the *Oregon Pesticide Applicator Manual: A Guide to the Safe Use and Handling of Pesticides* (EM 8532).

Field growers have a broad selection of preemergence and postemergence herbicides. Preemergence herbicides are applied before weed emergence to prevent weed establishment. In contrast, postemergence herbicides kill weeds after they have emerged and are actively growing.

The most effective and efficient weed management programs use a combination of sanitation, cultural practices, and preemergence herbicides to prevent weed establishment. Postemergence herbicides are effective at removing weeds that escape other measures.

Preemergence herbicides

Preemergence herbicides must be applied prior to weed seed germination. They do not control weeds present at the time of application (Figure 8). Two exceptions are *spray-applied* Goal (oxyfluorfen) and SureGuard (flumioxazin), which can kill weed seedlings less than 4 inches tall. However, use of these products is limited to conifers or directed applications on established deciduous plants.

Existing weeds must be removed or killed prior to application of preemergence

Figure 7. Living mulches between nursery rows provide weed control and have numerous beneficial impacts on soil properties.

Figure 8. Even small weeds can have deep root systems already growing below the chemical barrier, making preemergence herbicides ineffective.

herbicides. Weeds present at the time of herbicide application will continue to grow and produce seed, thus perpetuating the problem. Applying preemergence herbicides to fields where weeds are growing is a waste of herbicide and labor (a costly mistake).

Maintaining the chemical barrier

Preemergence herbicides form a chemical barrier over the soil surface. Although each class of herbicide controls weeds differently, preemergence herbicides provide control at the point where germinating seeds emerge through the chemical barrier (Figure 9).

If the chemical barrier is incomplete, there will be a gap where weed seed can germinate and grow. Equipment and foot traffic through treated areas can disrupt the chemical barrier and create gaps that allow weed seed germination. Minimize these activities to prevent disruption of the chemical barrier.

Sufficient and uniform herbicide application

To create an effective chemical barrier over the soil surface, always apply herbicides at the rate specified on the label. If rates are too low, the chemical barrier may not be sufficient to prevent weed growth. If rates are too high, the herbicide may cause crop injury.

It is important to apply herbicides uniformly. When herbicides are not applied uniformly, weeds will emerge in areas with insufficient herbicide. Use properly calibrated equipment that is functioning correctly.

Even with correct application, however, flaws in equipment setup may result in non-uniform applications. The most common mistake in spraying herbicides is using spray booms with different nozzles and thus different outputs. Be sure all nozzles on the boom are the same type.

Some pesticides are abrasive to metal, thus causing nozzles to gradually wear and develop a larger orifice. Some herbicides coagulate and clog nozzles and/or filters that are not cleaned regularly. Change nozzles yearly to ensure proper performance, and clean nozzles and filters monthly to prevent clogging.

A simple test can be used to check uniformity of nozzle output. Develop a method for collecting water from each nozzle; for example, hang buckets from the boom (Figure 10). Run the sprayer for several minutes with water only, and verify that output from each nozzle is the same. Be warned, simply looking at the spray pattern from each nozzle is not sufficient for spotting a malfunctioning nozzle.

Incorporating the herbicide

Preemergence herbicides sprayed on the soil surface initially create a very thin and highly concentrated layer on the soil surface. These herbicides should be *incorporated*

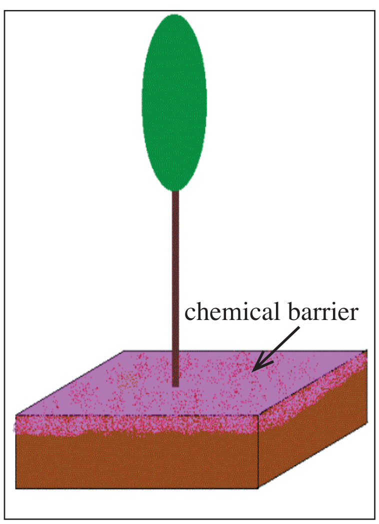

Figure 9. Preemergence herbicides form a chemical barrier over the soil surface.

Figure 10. Buckets hang from this boom sprayer to verify that output is uniform between nozzles.

or moved into the soil to a depth of 1 inch. In field nurseries this is accomplished with overhead irrigation or rain. Most preemergence herbicides can be incorporated to this depth with ½ inch of irrigation soon after application. (Check the herbicide label for specific instructions.)

Herbicide incorporation is a critical step in herbicide management. There are three common mistakes made with herbicide incorporation.

First, drip irrigation cannot be used to incorporate herbicides. Capillary movement of water will not move the herbicide downward into the soil to form a chemical barrier. Overhead sprinklers or rain must be used for this purpose.

The second mistake is incorrect use of rain for incorporating herbicide. Many herbicide labels state that the herbicide will be effective as long as it is incorporated within 3 weeks. The ideal circumstance is to have a single rain event soon after application that provides the complete volume of water needed for incorporation (½ inch).

Many people assume the herbicide will be adequately incorporated as long as the *cumulative* rainfall over 3 weeks is greater than ½ inch. However, observations on sandy soils in Oregon have shown that if soil is allowed to dry after the initial irrigation, the herbicide will bind to the soil and is unlikely to move thereafter.

Repeated cycles of small rain events followed by intermittent dry spells will cause the herbicide to bind tightly to the top layer of soil instead of moving into the top 1 inch of soil. The net effect is that the chemical barrier is not deep enough to control germinating weeds. Under these circumstances, weeds can germinate under the thin chemical barrier and grow through it.

Figure 11. Overhead irrigation is the most reliable method for incorporating herbicides.

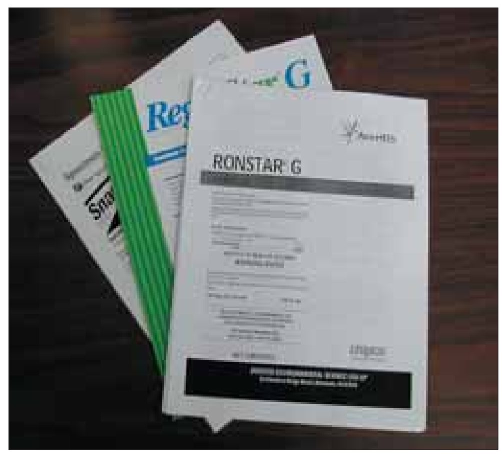

Figure 12. Select herbicides based on crop tolerance and weed susceptibility.

A third problem is rapid germination of weed seed prior to herbicide incorporation. Weed seed germinates within several days after soil is prepared for planting the crop. As mentioned above, some herbicides allow up to 3 weeks for incorporation. However, prior to incorporation, herbicides create a very thin and highly concentrated layer on the soil surface. Some weed seed may germinate under and grow through the thin chemical barrier, suffering little adverse effect. Thus, incorporating the herbicide as soon as possible after application will result in better herbicide performance.

In short, it is better to incorporate the herbicide with overhead irrigation than to rely on rain (Figure 11).

Selecting preemergence herbicides

Select preemergence herbicides based on crop tolerance to the herbicide and weed species to be controlled (Figure 12).

Crop tolerance to herbicides. It is important to select an herbicide based on the crop being grown. Every herbicide label describes how the product should be used and to which plants it can be applied. The plant list indicates plants to which the herbicide has been applied safely in experimental tests.

Every effort is made by chemical manufacturers to ensure that plants listed on labels can be treated safely. However, not every environmental or cultural situation can be predicted or accounted for when testing products. Therefore, prior to using a new herbicide, or before using a familiar herbicide on a new crop, conduct a small trial to ensure that the plant and herbicide are compatible under conditions specific to your production system.

Some labels specify whether the product can be applied to container crops, field crops, or both. Most labels specify which *species* can be treated; some list only the *genus*. The issue is especially complicated for nurseries because the horticulture industry frequently introduces new cultivars, species, and even genera. In Oregon, more than 2,000 species, varieties, and cultivars are grown commercially. Conducting small trials at the nursery prior to widespread usage is the only way to be sure crops are tolerant to a specific herbicide.

It is illegal to apply pesticides to crops not listed on the label. Never assume that plants closely related to those on a label can be treated safely with an herbicide.

Figure 13. Girdling of red maple liners caused by improper use of prodiamine. Prodiamine is not labeled for use on this species.

For example, herbicides containing prodiamine can cause severe girdling of small, recently planted red maple (*Acer rubrum*) liners (Figure 13). Some growers have mistakenly assumed that because closely related species (*A. palmatum* and *A. platanoides*) are on the label for this product, red maple also is tolerant. This has been a costly mistake for several producers. Never assume products are safe on nonlabeled crops, regardless of how many closely related species are listed on the label.

Weed susceptibility to herbicide types. No single preemergence herbicide provides complete control of all weed species. When a single chemical is used, poor weed control may result due to infestation by uncontrolled species.

Herbicides generally are effective on *either* broadleaf weeds *or* grasses. The following herbicides are effective in controlling emerging broadleaf weeds but provide only moderate control of some grasses: Goal (oxyfluorfen), Gallery (isoxaben), SureGuard (flumioxazin), and Princep (simazine).

Herbicides that are effective at controlling emerging grasses and *some* small-seeded broadleaf weeds (but not all broadleaf weeds) include Surflan (oryzalin), Pendulum (pendimethalin), Princep (simazine), Devrinol (napropamide), Pennant (metolachlor), and Barricade (prodiamine).

Table 1 (page 9) lists the types of weeds controlled by preemergence herbicides used in nursery production.

Sprayable preemergence herbicides labeled for nursery crops are sold separately; combination products are not available. For broad-spectrum weed control, tank mix one product listed in Table 1 for broadleaf weed control and another listed for controlling grasses. Refer to the label of both products to be sure they are compatible for tank mixing.

Timing preemergence herbicide applications

Apply preemergence herbicides in the spring and fall, with perhaps a midseason application. Apply these herbicides to established field stock in the spring as soon as field conditions permit or just after

Table 1. Preemergence herbicides commonly used in field nursery production.

Trade name	Active ingredient	Chemical class	Site of action	Weed control strengths
Gallery	isoxaben	benzamide	cellulose inhibitor	broadleafs
Goal	oxyfluorfen	diphenyl ether	PPO inhibitor[1]	broadleafs
SureGuard	flumioxazin	phenylphthalimide	PPO inhibitor[1]	broadleafs
Princep	simazine	triazine	photosystem II inhibitor	broadleafs
Devrinol	napropamide	acetamide	fatty acid inhibitor	grasses
Lasso	alachlor	chloroacetamide	fatty acid inhibitor	grasses, sedges
Pennant	metolachlor	chloroacetamide	fatty acid inhibitor	sedges, grasses
Kerb	pronamide or propyzamide	benzamide	microtubule assembly inhibitor	winter annuals
Casoron	dichlobenil	nitrile	cellulose inhibitor	broadleafs
Surflan	oryzalin	dinitroaniline	microtubule assembly inhibitor	grasses
Pendulum	pendimethalin	dinitroaniline	microtubule assembly inhibitor	grasses
Factor, Barricade	prodiamine	dinitroaniline	microtubule assembly inhibitor	grasses
Ronstar	oxadiazon	oxadiazole	PPO inhibitor[1]	broadleafs, grasses, not chickweed

[1] Protoporphyrinogen oxidase inhibitor

planting new stock. Make a second application in the fall to control winter annual weeds.

Herbicides at planting. Herbicides can and should be applied soon after planting. After planting, first irrigate fields with approximately ½ to 1 inch of water to settle the soil. Many field growers settle the ground by firming the soil with their feet. Stepping or stomping is not as effective at settling soil as water. Always irrigate for the most efficient soil settling. Apply preemergence herbicides 1 to 3 days after soil is settled.

If herbicides are applied immediately after planting, before settling has occurred, macropores in the soil may allow herbicides to channel into the soil and contact plant roots, thus causing injury or stunting. If herbicides are withheld for too long after planting, weed seed germination may occur.

Spring herbicide applications. For crops already in the field, preemergence herbicides typically are applied in March. Following this application, foot traffic and other field activity (staking, pruning, removing suckers, etc.) disrupts the chemical barrier. Typical herbicide degradation, combined with deterioration by field activity, will reduce the integrity of the chemical barrier well ahead of its expected duration of efficacy (4 to 6 months).

Early summer application. Many summer annual weeds germinate in late May or early June, after the initial herbicide barrier is depleted. An application in late spring or early summer (May or June) to reinforce the depleted spring application will dramatically improve weed control throughout the summer.

Fall application. Make a final preemergence herbicide application in late summer or early fall. This application will control winter annuals such as shepherdspurse (*Capsella bursa-pastoris*) and chickweed (*Stellaria media*). Preemergence herbicides persist longer in cool winter conditions than during the summer. When applied to weed-free soil in early fall, these herbicides can provide effective control into late spring the following year.

Mulches for preemergence weed control

Mulches can be used for weed control in nursery production, although their use is not common due to high cost and inefficient application. Nonetheless, mulches can provide preemergence weed control among herbicide-sensitive crops or in situations where chemical herbicides are otherwise not desirable.

Mulches form a barrier that prevents light from reaching the soil to cue germination of weed seeds. Most types of mulch are adequate for covering the soil surface and reducing light penetration. However, many types of mulch fail because the mulch itself becomes a substrate for weed germination. That is, weed seeds introduced after the mulch is applied (blown in by the wind, for example) germinate in the mulch.

A mulch used for weed control should be regionally abundant and affordable, have no nutrient availability, hold little water, and resist decomposition. Many agricultural by-products are abundant and affordable in the Willamette Valley. Only a few have desirable chemical and physical properties that make them appropriate for use in nurseries.

Mulches should contain little or no available nutrients. Weeds germinate and establish poorly in low-nutrient (especially low-nitrogen) environments. Many commercial composts have abundant available nutrients and thus are not desirable for use as mulch.

Mulches should dry quickly and not retain water. While it is desirable for the mulch to conserve water in the soil, the mulch itself should not retain water. A mulch with little or no moisture-holding capacity provides an environment inhospitable for weed establishment. Use mulches with coarse grades or large particles. For example, large bark nuggets retain very little water compared to bark dust.

Mulches should resist decomposition; they should be stable for many months in a nursery environment. As mulches decompose, they release nutrients that become available to germinating weeds. Decomposition also reduces the physical barrier that prevents light from reaching the soil surface. Products with large particle size generally decompose more slowly than the same material with a smaller particle size. For example, wood chips decompose more slowly than sawdust.

Douglas-fir bark, wood chips, coarse sawdust, and hazelnut shells are commercially available and abundant products that work as mulch in field nurseries. Medium- to coarse-grade Douglas-fir bark provides excellent weed control. The material has virtually no available nitrogen, is hydrophobic, and resists decomposition. However, Douglas-fir bark may cost too much to use as mulch in large field operations.

Large wood chips (¼ to 1 inch particle size) also work well and cost less than bark. Sawdust probably is the least expensive material, and it is commonly used by blueberry growers for weed control. In blueberry crops, a sawdust layer 3 to 4 inches thick normally lasts 3 years, long enough to span the production cycle of most nursery crops.

Hazelnut shells are inexpensive and work well; however, their availability is seasonal since hazelnuts are harvested October through November.

Phase III: Eradicate escaped weeds

Some weeds escape preventive control efforts. Remove these weeds by hoeing, cultivation, or spraying postemergence herbicides. Control escaped weeds before they reproduce by seeds or spread vegetatively.

Hoeing and cultivation are effective for removing annual weeds. Hoeing can be done precisely and is useful for controlling weeds close to the nursery crop. Hoeing is practical only for small weed populations. Cultivation can be done with power equipment and thus is more efficient over large areas, although equipment generally cannot function safely close to the crop (Figure 14, page 11).

Postemergence herbicides can be applied by broadcast spraying or spot spraying. Broadcast applications are more efficient, but are an option only if the crop is tolerant of the herbicide or if the sprays can be directed to the weeds while avoiding the crop. Spot spraying is effective for removing small patches of weeds.

Preventive weed control in Phase II poses less potential for injury to the nursery crop than weed removal efforts in Phase III. Emphasize preventive weed management efforts to minimize the need for postemergence weed control.

Figure 14. Hoeing is an expensive component of weed control and should be minimized.

Figure 15. A sublethal dose of Roundup causes stunting and foliar rosetting on holly.

Postemergence herbicides

Postemergence herbicides are used to kill actively growing weeds. There are two ways to categorize postemergence herbicides: (1) contact versus translocated herbicides, and (2) selective versus nonselective herbicides.

Contact versus translocated

Contact herbicides kill only the part of the plant they contact. When using contact herbicides, thorough coverage of the weed is essential. It is possible to spray and kill half of a weed, while allowing the other half to continue growing and producing seed. Contact herbicides will not affect root systems or other underground storage tissue such as rhizomes, tubers, corms, bulbs, taproots, etc.

Translocated herbicides are absorbed by the foliage, roots and, in some cases, green stems. They move through the plant to stems, roots, and underground storage tissues. Translocated herbicides are ideal for killing plants with well-developed root systems.

When possible, use contact herbicides around nursery crops because they generally are less damaging to the crop. If the herbicide accidentally contacts a nursery plant, it will injure only the leaves contacted. At worst, it will cause minor, localized foliar burn that the plant should outgrow.

In the case of a translocated herbicide, minor contact with the nursery crop could cause severe injury, although it may not be immediately noticeable. Small amounts of translocated herbicide can be moved throughout the plant and accumulate in root and shoot tips. This type of sublethal dose might not kill the plant, but it might cause stunting, malformed foliage, poor root growth, or foliar rosetting (Figure 15). Injured root systems can reduce plant vigor and cause stress that leaves the plant more susceptible to insects and disease.

Use contact herbicides as a first choice; however, use translocated herbicides for controlling established perennial weeds.

Selective versus nonselective

Selective herbicides kill only a certain type of plant, while not harming others. For example, Fusilade controls grasses but will not injure most broadleaf plants. This and similar products are commonly used to remove grasses from nursery crops because of their demonstrated safety when sprayed directly over the top of a broad spectrum of woody and herbaceous species.

Table 2. Postemergence herbicides commonly used in nursery production.

Trade name	Active ingredient	Chemical class	Site of action	Plant activity	Weed activity
Goal	oxyfluorfen	diphenyl ether	PPO inhibitor[1]	contact	nonselective, although weak on grasses
SureGuard	flumioxazin	phenylphthalimide	PPO inhibitor[1]	contact	nonselective, although weak on grasses
Vantage	sethoxydim	cyclohexanedione	ACCase inhibitor[2]	translocated	selective for grasses
Envoy	clethodim	cyclohexanedione	ACCase inhibitor	translocated	selective for grasses
Fusilade	fluazifop-p-butyl	aryloxyphenoxy propionate	ACCase inhibitor	translocated	selective for grasses
Roundup	glyphosate	amino acid derivative	EPSP synthase inhibitor[3]	translocated	nonselective
Finale	glufosinate	amino acid derivative	glutamine synthesis inhibitor	contact	nonselective
Gramoxone	paraquat	bipyridilium	photosytem I electron diverter	contact	nonselective
Reward	diquat	bipyridilium	photosytem I electron diverter	contact	nonselective
Basagran	bentazon	benzothiadiazole	photosystem II inhibitor	somewhat translocated	nutsedge, some broadleafs
Manage	halosulfuron	sulfonylurea	ALS inhibitor[4]	translocated	nutsedge, some broadleafs
Lontrel	clopyralid	picolinic acid	synthetic auxin	translocated	selective for composites, legumes, and some other broadleafs
various	2,4-D	phenoxy acid	synthetic auxin	translocated	selective for broadleafs

[1] Protoporphyrinogen oxidase inhibitor

[2] Acetyl co-A carboxylase inhibitor

[3] Enolpyruvylshikimate phosphate synthase

[4] Acetolactate synthase inhibitor

Nonselective herbicides kill all plants, regardless of type. Roundup is the most commonly used nonselective herbicide. Table 2 (page 12) lists commonly used postemergence herbicides and indicates whether they are selective.

Nonselective herbicides can be sprayed near nursery crops; however, the sprays must be *directed* so that contact with the crop is avoided. Many young trees (caliper less than 2 inches) have thin, green bark. Herbicides applied to thin, green bark can, and often do, cause injury. In some circumstances, herbicides can injure trees even if they are not green barked. For maximum safety to the nursery crop, avoid contacting any part of the plant with herbicide spray.

Herbicide coverage

Thorough coverage of plant foliage is important for postemergence herbicides.

Figure 16. Poor coverage with a contact herbicide allowed this weed to continue growing.

For contact herbicides, parts of the plant not contacted by the spray likely will survive (Figure 16). Plants that develop a large or thick canopy can shield themselves from herbicides. A contact herbicide may burn off a weed's outer canopy, leaving the inner canopy and stems relatively unaffected. Many weeds quickly grow out of this type of injury. This is the primary reason why contact herbicides are more effective on small weeds.

Thorough coverage also is essential for translocated herbicides. The more foliage contacted, the more herbicide will be absorbed, and the more will be shuttled to underground storage tissue. Large weeds likely have large root systems, so thorough coverage is paramount for attaining complete control. For example, field bindweed roots can grow 30 feet deep (Ross and Lembi, 1999). Thorough coverage is necessary to maximize herbicide uptake and the percentage of the root system controlled.

Factors affecting herbicide movement

Plants have a vascular system for moving food (sugars) and water from one part of the plant to another. The vascular system is made up of two components, xylem and phloem. Xylem transports water (with some dissolved nutrients) from roots upward to shoots, with virtually no downward movement. Phloem transports sugar, water, metabolites, and other substances (e.g., herbicides) in all directions throughout the plant.

Translocated herbicides move with the flow of sugar. Sugars generally are moved to "sinks," or areas that require energy for rapid growth. Sugars generated in the upper foliage of a stem generally move to that stem's growing tip or to developing fruit and flowers. Sugars generated in lower foliage generally move to developing roots. Thorough coverage of the plant (inner and outer canopy) will result in greater amounts of translocated herbicides moved throughout the *entire* plant, and thus more complete control.

Climate greatly affects postemergence herbicide efficacy. This is especially true with translocated herbicides. Factors that promote plant growth generally improve herbicide effectiveness. Stressed plants are more difficult to kill than healthy, actively growing plants. Drought and heat are the most common sources of weed stress that reduce herbicide efficacy.

During times of stress, photosynthesis slows, plants become metabolically less active, and movement of sugar throughout the plant is reduced. Therefore, stressed plants are less likely to move translocated herbicides to the root system, and control is reduced.

For perennial weeds with extensive root systems, fall may be the best time for application. When many weeds first set flower buds, plants begin to shuttle sugars and carbohydrates back to the root system for storage over the dormant season. Translocated herbicides are moved with these sugars; thus, increased amounts of herbicide move to roots during late summer or early fall. However, waiting this long may not be practical in some situations.

Commonly used postemergence herbicides

Fusilade, Vantage, and Envoy

These products are grass-selective translocated herbicides effective at controlling grasses without harming most broadleaf plants. They kill only grasses, or more precisely, plants in the family Poaceae.

Some plants resemble grasses, but are not in the grass family and thus are not controlled by these products. Notable examples are nutgrass (or nutsedge, *Cyperus esculentus* in the family Cyperaceae) and toad rush (*Juncus bufonius* in the family Juncaceae; Figure 17).

Roundup and other products containing glyphosate

Glyphosate is the active ingredient in Roundup. Since the patent for glyphosate expired, many companies have introduced new products containing glyphosate.

Roundup is a nonselective, translocated herbicide. It is one of the most widely used and effective herbicides. For annual weeds less than 6 inches tall, apply glyphosate as a 1 percent solution; for weeds greater than 6 inches tall, use a 2 percent solution; and for perennial weeds use a 3 to 5 percent solution.

Finale

The active ingredient in Finale is glufosinate, which is chemically similar to glyphosate. However, unlike Roundup, Finale is poorly translocated in plants. In fact, it is primarily considered a contact herbicide. Finale and Gramoxone (discussed below) have similar uses; however, Finale is less toxic to humans than Gramoxone.

Figure 17. Toad rush (Juncus bufonius) *looks like a grass; however, it is not in the grass family and is not controlled by grass-selective herbicides.*

Gramoxone and Reward

Paraquat and diquat are the active ingredients in Gramoxone and Reward, respectively. These products are similar in chemistry and mode of action. Both are nonselective contact herbicides that cause rapid injury to sprayed plants. Diquat can be used in greenhouses. Paraquat is highly toxic to humans and should be used with extra caution.

Goal

Goal contains the active ingredient oxyfluorfen. It is commonly used as a preemergence herbicide, although it also can be used as a nonselective contact herbicide for small weeds (less than 4 inches tall). Goal is commonly used in conifer production, where it can be safely applied over the top of many dormant conifers. Use caution around deciduous plants; directed sprays are necessary.

Scythe

Scythe is a nonselective, contact herbicide derived from naturally occurring pelargonic acid. Scythe works better on warm, sunny days when the temperature is above 70ºF.

Basagran and Manage

These products are in different chemical families and utilize different modes of action. They are effective for controlling yellow nutsedge and generally are limited to this application. Both can cause injury to nursery crops and therefore should be applied as directed sprays.

Other considerations

Herbicide resistance and weed shifts

Weeds can evolve resistance to herbicides with repeated use of the same or similar products. For a thorough discussion of herbicide resistance, refer to the Pacific Northwest Extension publication *Herbicide-Resistant Weeds and Their Management* (PNW 437). Below, we discuss important issues regarding weed shifts and development of herbicide resistance relevant to nursery production.

A *weed shift* occurs when repeated use of a single herbicide results in a gradual buildup of the population of a weed species tolerant of that chemical. For example, constant use of Ronstar alone might result in a shift to common chickweed (Figure 18)

Herbicide-resistant weeds occur when repeated use of herbicides with the same site of action allows resistant biotypes to survive, reproduce, and eventually become the dominant biotype in the field. Herbicide-resistant weeds occur naturally within the weed population, although in very low numbers. Resistant biotypes appear similar to and are sexually compatible with susceptible biotypes; they differ only in their ability to resist a specific herbicide activity.

Herbicides can be categorized by their site (or mode) of action. Site of action is the biochemical process or cellular site at which the herbicide alters or inhibits a necessary plant function, resulting in weed control. Herbicide-resistant weeds generally are resistant to all products categorized by the same site of action. Tables 1 and 2 list the site of action for each product.

Of herbicides labeled for nursery production, weeds are most likely to develop resistance to those classified as ACCase inhibitors (Envoy, Fusilade, and Vantage) and ALS inhibitors (Manage). Herbicide resistance to glyphosate is rare, but it has occurred in some species in Oregon. Because glyphosate is such a valuable weed management tool, its future use should be protected by moderating its use today.

Figure 18. A weed shift to common chickweed was caused by repeated use of oxadiazon.

The most effective way to prevent herbicide resistance is to avoid exclusive use over 2 consecutive years of products categorized by the same site of action. There are several nonselective herbicides besides glyphosate, including glufosinate (Finale), paraquat (Gramoxone), diquat (Reward), and pelargonic acid (Scythe). Rotate products occasionally to deter development of glyphosate resistance.

ACCase-inhibiting herbicides are valuable for their ability to selectively and safely remove grasses from nursery crops. They are so easy to use that many growers rely too much on these products for grass control. Development of resistance to these products in grass weeds would cause serious problems for nursery producers. Change management practices in order to *prevent* grass populations, thus limiting the need for selective postemergence grass herbicides.

Crop rotation also is effective for preventing herbicide resistance. Rotate fields among types of nursery crops to allow use of different weed control methods. For example, there are limited tools (including herbicides) for weed control in nursery seedbeds. Thus, in many cases, ACCase-inhibiting herbicides are used excessively in seedbeds. However, fields can be rotated out of seedbeds into fallow or production of more mature trees so that other herbicidal and mechanical weed control options can be used.

Tillage during fallow

Tillage or cultivation has been used in nurseries for decades as a tool for reducing weed populations. Repeated tillage throughout the summer fallow season can help control summer annuals or perennials.

Repeated tillage reduces the weed seed bank by allowing weeds to germinate and then tilling them under. The more seeds that germinate the more will be killed, so irrigate and fertilize to promote germination. Repeat tillage as often as necessary to kill seedlings before they mature and produce seed. Deep tillage may bring deeply buried seed to the soil surface.

Repeated deep tillage can be used to eradicate perennial weeds. Deep tillage mechanically destroys or severs perennial roots, rhizomes, and other underground storage tissues. Through repeated deep tillage, weed root systems must expend stored energy to regenerate. They eventually exhaust their energy reserves and die.

Do not allow plant shoots to regenerate enough to be able to produce photosynthates to replenish the root system. Many perennial species require 3 weeks to recover and begin regenerating their root system (Appleby, 1999). Tillage every 3 weeks will kill Canada thistle in a single year; however, many weeds require at least 2 years of repeated tillage.

Repeated tillage can have negative consequences on soil structure and long-term soil productivity. Consider planting the field with a dense cover crop immediately following the above-described tillage regime. Dense cover crops can help rebuild damaged soil structure.

Additional reading

Appleby, A. 1999. Weed control with tillage and mowing, some principles. Crop and Soil News/Notes 13(2).

Grundy A.C. and N.E. Jones. 2002. What is the weed seed bank? *In* Weed Management Handbook, 9th ed. Blackwell Science, Oxford, England.

Liebman, M., C.L. Mohler, and C.P. Staver. 2001. Ecological Management of Agricultural Weeds. Cambridge University Press, New York.

Ross, M.A. and C.A. Lembi. 1999. Applied Weed Science. Burgess Publishing Co., Minneapolis, MN.

OSU Extension publications

Common Weeds in Oregon Container Crops (EM 8874).

Herbicide-resistant Weeds and Their Management (PNW 437).

How Herbicides Work: Uptake, Translocation, and Mode of Action (EM 8785).

Oregon Pesticide Applicator Manual: A Guide to the Safe Use and Handling of Pesticides (EM 8532).

Pacific Northwest's Least Wanted List: Invasive Weed Identification and Management (EC 1563).

Perennial Weed Biology and Management (EM 8776).

PNW Weed Management Handbook (WEED).

Tank-mixing Herbicides (PNW 255).

Weed Control in Container Crops (EM 8823).

Weeds of the West (WEST).

Visit the online catalog (http://extension.oregonstate.edu) or call 541-737-2513 for prices and ordering information.

Summary

- Plant as soon as possible after field preparation.
- Practice good sanitation; control wind-blown seed; and manage fertilizer, irrigation, and tillage to create an inhospitable environment for weeds.
- Apply preemergence herbicides uniformly. Incorporate with irrigation and minimize disturbance of the chemical barrier.
- Eradicate escaped weeds by hoeing, cultivating, or spraying postemergence herbicides.
- Apply postemergence herbicides when weeds are actively growing. Spray for thorough coverage.
- Alternate herbicides with different modes of action.

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