

A Management Plan for Weeds in Production Nurseries

Weed management is one of the most important and costly aspects of container nursery production. Nursery environments are highly favourable for weed growth due to the high rates of irrigation and nutrition. Weeds reduce the rate of crop growth, crop saleability and spread pests down the supply chain. Weed management is most effectively achieved by using a combination of cultural, physical and chemical strategies to prevent weeds from establishing. Preventing weeds from flowering and seeding is the single most important strategy for weed control. Weed seeds are the most important weed source and can be distributed by people, animals, birds, wind and water. This paper provides information on the common weeds found in Australian production nurseries and management practices that provide effective weed control.



INTRODUCTION

Any plant that is not intentionally being grown in a container can be considered a weed. The most troublesome weeds are those that grow and reproduce quickly and have seeds that are easily dispersed. However, even slow growing plants and trees can become weeds if they are not proactively managed. Production nurseries contend with different weed species compared to other cropping systems, and typically each nursery will have its own specific set of weeds to manage. Weed species shift with change of seasons, but due to the nature of production nurseries

some may persist all year. Other factors that may influence weed species present in a nursery include geographic region, surrounding vegetation, management of new stock, foot and vehicular traffic and the efficacy of existing weed management strategies.

Weed management can be one of the most significant input costs to production. In container-grown nursery stock, weeds use nutrients, water, and light, and reduce root volume in a container. Just one weed in a small pot can impact plant growth for

certain crop species, dependent on size and species of the weed. With enough containers infested, weeds may lead to poor crop uniformity. The presence of weeds damages the aesthetics of the plant, affecting saleability of the crop. Weeds may also contribute to disease load by harbouring insects, pests, and pathogens and applications of crop amendments may be hindered if containers are weed infested.

Weed infestations can have serious economic impacts on nursery businesses. In severe cases, the cost of hand-weeding alone may account for approximately 30% of production costs. The integration of a wide range of management strategies is the most effective way to control weeds. Do not rely solely on herbicides to manage weed populations, even if the cost of preemergence herbicides may be relatively low.

There are many strategies and tools available to manage weeds such that plants are sold without these pests. This document discusses the value in identifying weeds to understand basic aspects of their biology and allow for better management. Brief information on many of the most common production nursery weeds are provided. Next, cultural practices and hand weeding strategies are discussed with a view of preventing weeds from establishing and thriving in the nursery. Lastly, preemergence and postemergence herbicides are discussed including their management to reduce the likelihood of inducing herbicide resistance. Implementing consistent and proactive weed management actions is effective and can lead to a weed free environment.

WEED IDENTIFICATION, LIFECYCLE AND SEASONALITY

Developing a weed management program for your nursery requires an understanding of the different types of weeds present and the appropriate management options for each weed.

Most weeds are either broadleaf weeds or grassy weeds. *Grassy weeds* have hollow rounded stems, the nodes are hard and closed and display long leaves with parallel veins. *Sedges* (e.g. nutgrass) can be grouped with grasses on some herbicide labels but are not true grasses. Sedges have solid triangular-shaped stems with parallel-veined leaves that extend in three directions. *Broadleaf weeds* are highly variable in appearance, have net-like veins on leaves and display showy flowers. Weed problems are not only limited to higher plant forms - mosses and liverworts are also quite problematic in container nurseries, spread easily and are



Bittercress or Flickweed (*Cardamine* spp.) is a broadleaf winter annual weed. It can persist year-round in shaded moist environments and hand-weeding is difficult and time consuming. It is a prolific seed producer that develops dehiscent seed pods. Well controlled by products containing oryzalin + oxyflurofen and oxadiazon. Image by Joseph C. Neal.



Horseweed or Fleabane (*Conyza canadensis*) is a broadleaf winter annual weed that requires complete removal when hand-weeding, as it will resprout from a broken stem. Make sure to control around your property as seeds on tall stalks are spread via wind. Well controlled by products containing oryzalin + oxyflurofen and oxadiazon. Image by Joseph C. Neal.



Cudweed (*Gamochaeta purpurea*) is a broadleaf winter annual weed that can sometimes exist as a short-lived perennial. Seeds are wind dispersed, so control around the property will prevent seed spread into containers. Well controlled by products containing oryzalin + oxyflurofen, oryzalin, and oxadiazon. Image by Joseph C. Neal.

difficult to control. Aquatic weeds, like algae, may also pose a problem in water storages and on solid surfaces in production areas.

Weeds can be further grouped into three categories based on their lifecycle: annuals, perennials and biennials. Most container nursery weeds are annual weeds that complete their lifecycle within one year and are further characterised by seasonality. Summer annuals germinate from seed in spring/summer, then flower in summer and set seed. These weeds will typically decline in autumn/winter and will die below a certain temperature. Winter annuals germinate from seed in autumn, then seedlings overwinter and flower in spring. These weeds usually die above a certain temperature.

Despite the differentiation of annual weeds into cool and warm seasons, in a production nursery environment some weeds may persist all year-round depending on the conditions present. Additionally, warm season weeds can persist all year in subtropical and tropical regions.

Perennial weeds can live for more than two years, and typically spread by seed during spring and early summer. They are also capable of vegetative reproduction and are usually dormant in winter. Perennials are further divided into groups based on root system type and reproduction. Simple perennials reproduce by seed but can also spread via mechanically disturbed root fragments. These weeds die back in winter and regrow in spring. Bulbous perennials reproduce by both seed and bulbs. Creeping perennials reproduce by seed and rhizomes/tubers or stolons. The production of tubers or bulbs is influenced by season. Perennial weeds (especially sedges) are the most difficult to control due to their varied reproductive processes and persistence.

Biennial weeds have a two-year lifecycle. Vegetative growth occurs during the first year, and in the second year the weeds flower, seed and then die. During the growth phase biennial weeds produce a cluster of leaves near the soil surface. This period is the optimal time to control these weeds. Biennial weeds are more difficult to control than annual weeds, as the vegetative structures are more persistent and resilient. However, biennial weeds are not typically pests of production nurseries.

A successful container weed species displays the following characteristics: active seed dispersal (e.g. wind-blown, explosive dehiscence or water splash), germination in low light and moist environments, a short lifecycle that allows multiple generations per season (e.g. within a spraying or weeding cycle) and prolific seed production.



Summer grass (*Digitaria sanguinalis*) is a summer annual grassy weed. It is well controlled by preemergence chemicals such as oryzalin, oxyfluorfen and oxadiazon. Postemergence graminicides are also effective. Sanitation is also important for control. Image by Joseph C. Neal.



Winter grass (*Poa annua*) is a winter annual grassy weed. It is important to control plants before seed set in and around production areas. It is not well controlled by postemergence graminicides but is well controlled by most preemergence herbicides in containers. Image by Joseph C. Neal.



Nutgrass (*Cyperus rotundus* and *C. esculentus*) are perennial sedges that require regular hand-weeding, and typically the removal of the top 20mm of media in a container to prevent regrowth. Glyphosate is effective when used in non-production areas. Nutgrasses are unresponsive to graminicides. Image by Joseph C. Neal.



Pearlwort (*Sagina procumbens*) is a dicot winter annual weed that is grass-like in appearance. Plants prefer cool, moist conditions and seeds spread via water, therefore improving drainage aids in controlling this weed. Products containing oryzalin and oxyfluorfen work well for chemical control, whereas oxadiazon provides no control. Image by Joseph C. Neal.

It is recommended to identify and record all weed species in your nursery around three to four times per year (termed scouting – this is in addition to regular crop health monitoring). This information can be used to build or update a flexible weed management plan optimised for the reduction of weeds present. It is important to do this regularly as weed populations can change over seasons, and some control measures are not effective against certain weeds. If you need assistance to identify a commonly encountered weed (or plant) it is recommended to contact your local state herbarium ([ACT](#), [NSW](#), [NT](#), [Qld](#), [SA](#), [Tas](#), [Vic](#), [WA](#)). There are also a variety of plant identification apps that may assist, though it is recommended to verify that the identification is accurate before implementing management actions.

CULTURAL AND PHYSICAL WEED MANAGEMENT

Effective weed management uses cultural and physical practices to prevent entry of weeds into the nursery and reduce weed pressure passively. With appropriate cultural control measures in place the reliance on herbicides is reduced. This is ideal as most herbicides have a detrimental effect on at least some ornamental plants, especially during propagation.

Do not allow weeds to go to seed. Most nursery weed seeds can germinate within a week, and some can set seed within 3–4 weeks. Seeds can be distributed via wind (e.g. horseweed, groundsel, and hawksbeard), water-splash (chickweed and pearlwort) or explosive dehiscence. The latter is an effective seed dispersal mechanism, capable of spreading seeds up to 3.6 metres in woodsorrel and 1.8 metres in bittercress. Weeds such as phyllanthus and spurge can also spread seeds via dehiscence 60–90cm from the mother plant. Such weeds must be managed very proactively, even if plants are grown on benches.

Many of the practices described below minimise weed seeds in the production system and will greatly improve weed control. Put in place as many as possible such that regular management actions can be maintained, even during busy periods. Allowing weeds a foothold in the nursery (e.g. because business is too busy) can be very detrimental in the longer term and drastically increases costs (e.g. staff time, control actions, discarded plants or poor plant quality from weed infestations).



Weeds growing in non-cropping areas can quickly grow into container plants.

NURSERY HYGIENE AND CULTURAL PRACTICES

Nursery hygiene is important for preventing weed infestations and breaking the lifecycle of the weed in growing areas. There are also many growing practices that can substantially reduce weed populations passively. The following hygiene and cultural strategies are recommended:

- » **Inspect new plants** brought into the nursery and remove any weeds. It may be appropriate to discard the top 2cm of media in a weedy container. Consider changing suppliers that regularly provide weed infested containers or returning consignments where appropriate.
- » **Store media appropriately** to prevent contamination with weed seeds that are spread long distances via wind. Storing media undercover on a clean, sealed surface prevents contamination from weeds and pathogens. It also reduces exposure to sunlight and rain which encourage weed germination and growth.
- » **Disinfest growing surfaces** and remove all organic matter in growing areas between crops. This assists in breaking the lifecycle of weeds that may be present in the growing area.
- » **Ensure regular monitoring** of freshly potted plants for weeds (this is in addition to more comprehensive quarterly scouting events described in the identification section above). Any seeds present in the growing media are most likely to germinate once watered and fertilised. Regular germination of weeds in newly potted plants should be investigated to stop seeds from entering the system.
- » **Do not recycle growing media;** this practice substantially increases the risk of infection from a range of pests including soil borne pests and pathogens, as well as weeds.

- » **Dibble or incorporate fertiliser** into the growing media to avoid nutrients being available on the media surface. Avoid topdressing slow release fertiliser as this can promote weed development. Altering fertilising practices can reduce the growth of common nursery weeds by at least 85%.
- » **Filter and disinfect irrigation water.** Weed seeds, bryophyte spores and algae can be spread in water.
- » **Avoid overwatering** and allow for sufficient drainage of containers. Whenever possible, allow the surface of the growing medium to dry between irrigation cycles.
- » **Increase the air-filled porosity of growing media** to improve drainage, if possible. Coarse media, especially at the surface, that drains well is ideal to keep media dry. Coarse bark, perlite or vermiculite increases drainage, whereas peatmoss and fine bark increases water holding capacity.
- » **Use of raised benches** and/or coarse gravel improves water drainage by preventing water pooling under pots.
- » **Avoid moving containers infested with weeds.** Dehiscent seeds can be spread over the nursery easily during this process. Remove weeds prior to transfer or sale to limit spread of pests.
- » **Disinfect re-used trays and containers.** Re-used pots should be cleaned to remove organic matter and treated with heat for 30 minutes at 60°C. Disinfection with chlorine or other chemical products is not effective unless all organic matter is removed prior to treatment. Alternatively, use new, clean pots and trays.
- » **Store containers hygienically.** New and disinfested containers should be stored under cover and in such a way as to avoid contamination with organic matter.
- » **Disinfect tools, equipment, machinery** and vehicles to stop spread of diseases and weed seed.
- » **Manage discarded plants proactively.** Do not leave discarded plants in a heaped pile on site. Waste should be managed by composting or deep burial. Alternatively, discarded material can be covered and promptly removed from the site.
- » **Use organic or plastic mulch,** particularly for in-ground mother stock blocks, to minimise weed establishment. Weed mats or similar products are essential underneath containers in production areas. Ensure that organic mulches do not introduce weeds or fungal pathogens; it is not recommended to use 'forest mulch' type products. Coir weed mat covers can also be used as a surface mulch for containers and may be cost-effective in certain cases.



Phyllanthus (*Phyllanthus tenellus* and *P. urinaria*) is a broadleaf summer annual weed that may also occur as a perennial weed in subtropical environments. *P. tenellus* displays long seedpod stalks (above), whereas *P. urinaria* has very short seedpod stalks (below). Seed is spread by dehiscence. Both species are difficult to control as most preemergence herbicides listed for nursery use are not effective. It is recommended to hand-weed young *Phyllanthus* seedlings to prevent seeding. Images by Joseph C. Neal.



Woodsorrel or Oxalis (*Oxalis corniculata* (above) and *Oxalis stricta* (below)) are broadleaf winter annual species that can persist into summer. It is difficult and time consuming to hand weed. Once established in a container, it is difficult to completely remove the rhizomes and stolons. Seeds are spread by dehiscence. Well controlled by products containing oryzalin + oxyfluorfen, oryzalin and oxadiazon. Images by Joseph C. Neal.

- » **Do not retain old stock.** Discarding old, unsaleable stock assists in breaking the lifecycle of many pests including weeds, insects and diseases.
- » **Install [windbreaks](#) where appropriate.** If using hedges or bushy trees, ensure that they are not closely related to stock plants grown nearby as this can increase the risk for pest and disease incidence. Living plants used as a windbreak should be well maintained to avoid dieback.

HAND-WEEDING AND MOWING

Hand weeding often has a massive impact on weed pressure. [Research](#) has shown that hand weeding every two weeks, rather than every eight weeks, lowered labour costs by half over a 4–6 month period, and thus reduced overall weed growth by about 70%. Using this fortnightly approach, concentrate on removal of relatively large weeds that could potentially flower before the next cycle. Allow relatively small weeds that are less than a week old (which are the most time consuming to remove) to remain until the next hand weeding session, well before they flower and set seed. The exact timing and size category targeted may need to be altered depending on climate and weed species.

Ensure weeds are disposed hygienically, in covered bins or bays or bagged until they are removed from the site. Weeds left in or around the growing area may release seeds. Weeds in non-crop areas (such as the nursery perimeter, fencelines, driveways, and around irrigation sources) will inevitably move into production areas if they are not controlled. Mowing peripheral areas to prevent seeding is very effective.

HERBICIDES

Many production nurseries use herbicides as a component of their weed management plan. Be aware that herbicides will not eliminate the need for hand weeding, however their use will reduce overall weeding costs and time, dependent on the conditions in your nursery. Hand weeding of some species can spread the weed, e.g. [liverwort](#). Therefore, hand weeding should only be completed within an integrated frame work also applying an appropriate herbicide.

Herbicides are chemical compounds that interfere with plant growth and development. The weed response is dictated by the chemical concentration applied, and the type of herbicide used. Herbicides may be selective (products that only kill certain plants with little to no effect on others) or non-selective (toxic to most plants). In addition, herbicides may be systemic (moving throughout the plant) or contact



Willowherb (*Epilobium ciliatum*) is a broadleaf perennial weed, that exists occasionally as a winter annual. Prevent plants from going to seed in and around production areas to prevent spread, as seeds are wind dispersed. It is not well controlled by herbicides registered for nursery use. Images by Joseph C. Neal.



Thickhead (*Crassocephalum crepidioides*) is a broadleaf year-round annual weed that appears to be controlled by products containing oryzalin + oxyfluorfen, oryzalin and oxadiazon. Seeds are wind dispersed. Images by Joseph C. Neal.



Sowthistle (*Sonchus* spp., above) and **Wild Lettuce** (*Lactuca* spp., below) are broadleaf winter annual weeds that are well controlled by products containing oryzalin + oxyfluorfen, oryzalin and oxadiazon. Chlorthal dimethyl is somewhat effective. Seeds are wind dispersed. Images by Joseph C. Neal.

(effective only where the product has been applied to the plant). Every herbicide contains the chemical that provides the weed control (active ingredient) and a carrier or solubility agent (inert ingredient).

The mode of action (MoA) of a herbicide is determined by the mechanism of interference with plant function or metabolism. MoAs include disruption of enzymes, photosynthesis, protein or lipid synthesis, cell membranes, pigment synthesis or DNA synthesis. Herbicides with the same MoA typically have the same movement pattern, produce similar injury symptoms and require similar application methods. In Australia, there are 19 letter codes that [divide herbicides into each MoA group](#). [Refer to Table 1](#) for a list of currently registered herbicides in Australia for weed control in production nurseries and their MoA designations.

Herbicides are also differentiated by timing of application as either preemergence or postemergence. *Preemergence herbicides* are applied prior to weed emergence to prevent growth. These compounds are active against growing meristems of the weed on contact, and therefore do not work on established weeds. They are applied to the surface of weed-free container media and surrounding production areas. Overhead irrigation activates the herbicide to incorporate it into the growing media. Preemergence herbicides are typically effective on either broadleaf or grassy weeds, but they do not provide control of all weeds.

Postemergence herbicides are applied to actively growing weeds and are most effective when weeds are small. These compounds must remain on weed foliage for several hours to be effective. Some postemergence herbicides are specific for grasses (graminicides) and may be applied over the top of ornamentals. Non-selective postemergence herbicides such as glyphosate or paraquat+diquat may be used in non-crop areas for weed control, as they can injure crop plants.



Groundsel (*Senecio vulgaris*) is a broadleaf winter annual weed that is well controlled by oryzalin + oxyfluorfen. Seeds are wind dispersed. Image by Joseph C. Neal.



Hawksbeard (*Youngia japonica*) is a broadleaf summer annual weed that can persist year-round in nurseries and resembles dandelion. Seeds are wind dispersed. It appears to be well controlled by products containing oryzalin + oxyfluorfen, oryzalin and oxadiazon. Images by Joseph C. Neal.



Mouseear chickweed (*Cerastium fontanum* ssp. *vulgare*, above) and **Common chickweed** (*Stellaria media*, below) are broadleaf winter annual weeds. Mouseear chickweed can also be a short-lived perennial weed, whilst common chickweed can be present year-round in shaded moist areas. Both weeds can spread easily if hand-weeding is undertaken during seeding, as they are prolific seed producers. Splashing water also aids seed dispersal. Both species are well controlled by most preemergence herbicides suitable for container use, except oxadiazon. Images by Joseph C. Neal.

HERBICIDE MANAGEMENT OF WEEDS

There are four main factors to consider when selecting a herbicide: the crop, the weed species, weed growth stage and the herbicide MoA. Proper weed identification is crucial to the success of a herbicide management plan so that an appropriate herbicide is chosen. Even non-selective herbicides can have varying performances on different weeds.

Carefully read the chemical label to ensure the herbicide is not toxic to the crop plants in question. If in doubt, test the product on a small number of plants to determine if

Contact herbicides are fast acting and only affect the area of the weed contacted by the application. The herbicide may kill foliage, but regrowth from the roots is possible, so repeat applications are typically required.

Systemic herbicides act via translocation throughout the weed and may take days or weeks to do so. This action allows the entire weed to be exposed to the herbicide and is most effective during the active growth phase (when the weed is not stressed through drought, cold, seeding, after being mowed, etc.).

a phytotoxic reaction occurs. Early stages of container production in liners/flats are problematic for chemical control, as most herbicides are injurious to newly established ornamentals. Herbicide management in herbaceous plant production is more problematic than woody ornamentals, as they are less tolerant of preemergence herbicides due to sensitivity of foliage and growth habits.

The growing area where chemical weed control is required influences herbicide choice as some products are not able to be used within protected cropping structures or in production beds (Table 1). Most registered preemergence herbicides cannot be used in enclosed structures, due to concerns of phytotoxicity from direct contact with production crops, or from chemical volatilisation. A great deal of information on chemicals and their usage is available on the [Nursery Production FMS website](#), including the [Best Practice Manual for Pesticide Application](#) and all current minor use permits for the production nursery industry.

In most cases, a single herbicide does not control all weeds at a specific site. Combining herbicides may be useful to increase the spectrum of weeds controlled and reduce risk of inducing herbicide resistance. Certain preemergence herbicides are generally stronger on grassy weeds or broadleaf weeds. A tank-mix of specific herbicides will increase the spectrum of weeds controlled, assuming the products are compatible; [pesticide incompatibility](#) can cause product failure. Another factor to consider is the formulation of the herbicide, whether it be granular or spray. Granular products tend to be better suited to small containers as they limit foliage contact and drift. Most postemergence herbicides are applied as a solution to ensure thorough weed coverage, but this increases the chances of damage to crop foliage if used in production areas. Caution is also required with herbicide use around pot storage and media storage areas. Unintended herbicide injury on crop plants may occur immediately or long after application, depending on herbicide persistence/degradation.

PREEMERGENCE HERBICIDES

Preemergence herbicides require uniform application at the advised dose when crop foliage is dry. Ensure no herbicide is left on crop foliage as it may cause damage. It is then recommended to lightly water in the herbicide within 24 hours to incorporate into the media surface. However, be aware that excessive irrigation can impact herbicide efficacy by leaching away from the media surface. Chemical solubility influences the amount of water required for herbicide incorporation into the media and how easily



Spurges are broadleaf summer annual weeds that cover a range of species. Spurges flower when young and are prolific seed producers with little to no seed dormancy, meaning that populations can spread rapidly. Spurges are time consuming to hand weed as seedlings can be high in number, but it is recommended to remove plants when young to reduce seed load. Seeds are dispersed via dehiscence. Spurges are generally well controlled by products containing oryzalin + oxadiazon or oryzalin, whereas oxadiazon and oxyfluorfen are less effective. Chlorthal dimethyl is effective for about 4 weeks. **Garden spurge** or **asthma weed** (*Euphorbia hirta*, first image) is more easily controlled with herbicides than other spurges but does spread faster. **Hyssop spurge** (*Euphorbia hyssopifolia*, second image) appears to be more tolerant to herbicides than the other spurges. **Petty spurge** (*Euphorbia peplus*, third image) grows year-round in warmer regions, as does **Spotted spurge** or **caustic weed** (*Chamaesyce* spp., fourth image). Images by Joseph C. Neal.

FACTORS TO CONSIDER WHEN CHOOSING A HERBICIDE

- » The weed species
- » Weed development stage
- » Crops in production and their susceptibility to the chemical
- » Production environment type (structures and irrigation systems)
- » Season and prevailing weather conditions
- » Soil type
- » Mode of action (MoA) of chemical
- » Application method (spray or granular)
- » Application equipment needed
- » Staff access to area, risks to health and PPE required
- » Potential environmental risks
- » Cost

the germinating weed will absorb it. It also influences the potential for leaching further into the media causing crop injury or loss.

The amount of irrigation required and time between applications varies between different herbicides. Preemergence herbicides can last between 6 to 12 weeks, so reapplications are often necessary. Most importantly, preemergence herbicides require a complete chemical barrier to work well. Weed seeds can germinate and proliferate if there are gaps. Poking holes in the media surface (e.g. from drip irrigation spikes or stakes), moving or dropping containers, container blow-over and removal of existing weeds can all disturb the chemical barrier. If preemergence herbicides are applied to a container before the potting media has time to settle it can also break the chemical barrier and increase the risk of herbicide leaching. Check the product label for specified application rates to ensure uniformity and effectiveness.

There are restrictions to using some preemergence herbicides in production nurseries as they are not labelled for enclosed structures due to the high risk of phytotoxicity. For example, if the product evaporates in an enclosed structure it can cause leaf damage that would not occur if it was applied outside. In addition, herbicides containing dinitroanilines can inhibit root growth if permitted to move into the growing substrate. Enclosed spaces combined with high levels of irrigation during propagation increases the chances for phytotoxicity.

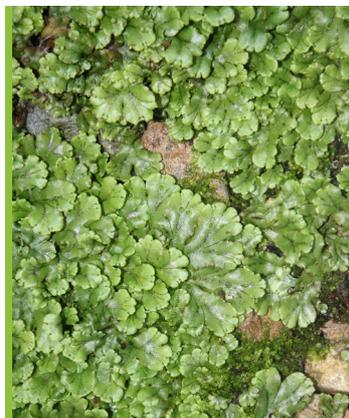
Some plant species are more likely to suffer from herbicide phytotoxicity (e.g. azaleas and herbaceous perennials; and ornamental grasses sensitive to dinitroaniline preemergence herbicides). It is recommended to trial products on a small batch of plants to establish their efficacy and observe potential phytotoxic effects prior to widespread usage. Such trials should have both treated and untreated plants of the same variety and size. Inclusion of treated and untreated plants in the trial is important as a point of comparison to ensure the treatment has worked correctly.

POSTEMERGENCE HERBICIDES

The range of plant species found in a typical nursery can make use of postemergence herbicides difficult, without causing phytotoxicity to at least some crops. Postemergence herbicides are generally non-selective and may provide broad-spectrum weed control if used carefully. Avoid applications directly onto crop foliage, and limit spray-drift. Herbicides such as glyphosate, glufosinate, paraquat+diquat and nonanoic acid are best used to control weeds in non-



Algae can be found in water storages, along pathways, under benches and other areas of the nursery. Algaecides are effective as a solid surface treatment. Algal blooms are observed as a colour change in the water supply or scum on the water surface. Refer to [Managing Algae in Water Storages](#) for more information. Image by DAF.



Liverwort (*Marchantia polymorpha*) is a bryophyte weed which is notoriously difficult to control. It prefers moist, cool conditions and is a prolific reproducer. There are limited options for herbicide control in containers so the best way to manage liverwort is via cultural practices. Refer to [Managing Liverworts in Production Nurseries](#) for specific information on liverwort control. Image by DAF.



Mosses are bryophytes that prefer cool moist environments and are prolific reproducers. Limit excess water availability in the nursery and use algaecides such as benzalkonium chloride or dichlorophen on pathways, under benches etc. Image by DAF.

production areas (e.g. pathways, under benches, fencelines, etc.) that do not drain into waterways or irrigation catchments.

Postemergence herbicides require a rain/irrigation-free period post-application. The most effective time to apply these chemicals are when weeds are actively growing and not under moisture stress. Weeds should not be mowed for 2 weeks prior to, and 1–2 weeks, after applying the herbicide. Modify the application rate based on the germination period and growth stage of specific weeds present at your nursery.

The easiest time to apply herbicides to existing weeds in a container production area is between crop cycles. Seedlings are very sensitive to most herbicides compared to large and mature plants. Despite the sensitivity of herbaceous plants, they can often tolerate postemergence graminicides well. Some herbicides are also temperature sensitive and activity may be reduced at cold temperatures. Also, volatilisation can occur at high temperatures increasing the risk of crop damage.

HERBICIDE DEGRADATION AND LEACHING

Herbicide persistence in soil and water is an important consideration when purchasing products for your business. Apart from the innate properties of herbicide chemistry and formulation, degradation varies with soil type, pH and moisture, temperature, light exposure, herbicide concentration and the amount of organic matter present. Sources of degradation include the following processes: photodegradation, chemical (hydrolysis) and microbial breakdown, leaching and volatilisation.

Microbial and photodegradation are the primary sources of herbicide degradation. Dry and cold conditions tend to slow degradation. Warmer temperatures, adequate soil conditions (moisture, oxygen and nutrients) and a neutral pH encourage soil microbe activity, and thus increase microbial degradation potential. Preemergence herbicide incorporation into the top few centimetres of media via irrigation will reduce the potential for photodegradation and volatilisation. Preemergence herbicide chemicals that are susceptible to photodegradation include simazine, oryzalin, pendimethalin, prodiamine and oxyfluorfen.

The half-life of a herbicide is the average time taken for half of the chemical to be broken down into other compounds. Less than 30 days is considered low persistence, 30–100 days is moderate, and more than 100 days is high. Herbicide persistence will affect the length of residual control. Many herbicides have little to no soil persistence, and therefore reapplications may be necessary. Long-lasting

herbicides may remain active in soil for years. Do not apply persistent herbicides in areas where surface runoff may occur, or where soil may contain tree or shrub roots.

As stated above, research the [half-life of herbicides in both soil and water](#) prior to purchase.

Herbicides may accumulate in [water storages](#). Growing bed materials and runoff drain construction are thought to influence the rate of herbicide runoff into dams and waterways. Weed mats combined with gravel appear to provide good capture of herbicide leachates, whereas concreted pathways and drains allow easy leachate runoff. Keep in mind that excessive irrigation results in herbicide leaching regardless of nursery design.

Media that is low in organic matter has less herbicide binding (adsorption) potential, which allows greater herbicide uptake for weeds, but increases leaching potential. Herbicides that bind tightly to soil typically require higher application rates for effective weed uptake, persisting for longer in media, but resulting in less leaching due to high adsorption rates.

EVALUATION OF HERBICIDE CONTROL

It is recommended to keep an accurate record of all herbicide applications and their results to evaluate the effectiveness of your herbicide management plan. Information recorded should include the application date, herbicide used and formulation, herbicide rate and spray volume output, weeds present and their growth stage, crops and their growth stage, location and size of area treated, the weather (such as temperature, wind speed and direction, and post application rainfall), irrigation scheduling, soil moisture, and any application problems that occurred. It is recommended to monitor weed populations post application (the exact timeframe after application will depend on the herbicide in question) to determine the success of treatment. Use this information to make appropriate adjustments to future herbicide applications.

HERBICIDE RESISTANCE AND ITS MANAGEMENT

If weeds that have been previously controlled with a specific herbicide are no longer controlled, a herbicide resistant population may have developed. Glyphosate resistance has developed in several weeds such as wimmera ryegrass and horseweed. Some weeds are naturally tolerant to specific herbicides, e.g. chickweed and pearlwort tolerance to oxadiazon. Regular use of herbicides on either resistant or tolerant weed populations can lead to an increase in abundance of those weeds.

However, most weed control failures are not due to herbicide resistance. Before assuming that weeds surviving post-application treatments are resistant, eliminate all other possible causes of poor control. Potential causes of weed control failure may include inefficient application (such as inadequate rate, poor coverage, or poor incorporation), unfavorable weather conditions for efficient herbicide activity, improper timing of herbicide application (in particular applying postemergence herbicides after weeds are too large for good control), and weeds emerging after application of a low persistence herbicide.

Once all other possible causes of poor herbicide control are assessed, the following may indicate the presence of a herbicide-resistant biotype:

- » The application has worked well on all weed species normally controlled except one
- » The weed species not controlled is normally susceptible to the herbicide used
- » Healthy plants of the weed species in question are scattered among plants that were killed
- » There is a history of extensive use of herbicide/s with the same mode of action

Resistance management guidelines have been developed to minimise the likelihood of inducing herbicide resistance. Simply rotating between products from different MoAs is not sufficient. The following recommendations will assist in managing herbicide resistance and reduce the chance of product accumulation in the growing environment and crop phytotoxicity.

- » Implement as many cultural and physical weed management practices as possible. This reduces the need to apply herbicides and is the most important part of managing herbicide resistance.
- » Follow any recommendations on the label to manage herbicide resistance. This includes the maximum number of applications per season or crop cycle.
- » Rotate between herbicides from different MoA groups.
- » Do not apply herbicides of the same MoA sequentially unless it is specifically recommended on the label.
- » Apply two or more herbicides from different MoA groups simultaneously or sequentially (on the same day).
- » Use products that are effective against weeds present in the nursery and apply at rates relevant to those weeds.

- » Use non-selective herbicides between crops and in non-growing areas as appropriate.

If herbicide resistance is suspected you should immediately stop using that herbicide and those from the same MoA group. Crop Life Australia lists MoA groups from high to low resistance risk, and details [weeds that have demonstrated resistance](#). Most weeds on the list are field production weeds, but there are some that are common to production nurseries.

Refer to Crop Life Australia's [herbicide resistance management strategies](#) or the Herbicide Resistance Action Committee's [herbicide resistance guidelines](#) for further information on herbicide use and resistance management.

HERBICIDE INJURY TO CROP PLANTS

Herbicide injury can easily be mistaken for symptoms caused by poor water quality, nutrient disorders, virus or phytoplasma infection, or infestations of broad mites and eriophyid mites. General herbicide injury symptoms include reduced plant growth and vigour, leaf malformations, leaf chlorosis (tip, veinal, interveinal, or marginal), leaf necrosis (marginal or spots) and inhibition of root development leading to stunted growth (e.g. caused by low soil oxygen, disease etc).



Plants with damage that may have been caused by herbicide.

Symptoms can typically be separated by the MoA of each chemical. Always compare treated crops to non-treated crops of the same plant line to aid in identifying potential injury symptoms. If in doubt, test a small number of plants (at multiple rates if possible) to better understand the effect of the herbicide on plant symptoms. Take pictures of the symptoms for later comparison. The [NC State Extension weed management website](#) has detailed information on nursery weeds, herbicides and injury symptoms for each herbicide group.

DECONTAMINATING A GROWING AREA

There are several actions that can be taken to deactivate herbicides in the event of accidental spills or accumulation of a product in a growing area causing crop injury. Firstly, identify the problematic herbicide through a process of deduction (examining previous records and or consulting historical production managers). Once a short list of potential herbicides have been created, it is recommended to confirm the presence of the product in the growing area or soil through laboratory testing. There are a number of service providers in Australia that complete this type of testing. The product present may influence the strategy taken.

Once herbicide is confirmed, consider the following management strategies.

- 1. Removal and appropriate disposal** of the contaminated soil or media. Contaminated soil or media may be physically removed from the plant root zone and disposed or stored appropriately. Disposal offsite may be expensive, depending on the type of herbicide. Onsite disposal may involve containing the contaminated soil/ media to prevent leaching into the environment until such a time as the product has been degraded through natural (or improved) degradation processes.
- 2. Hastening the degradation process** through adsorption (binding of the herbicide to deactivate it). The use of adsorbents such as organic material and clays will help bind the herbicide within the media, preventing uptake by the crop plant. Activated charcoal is a commonly used adsorbent and is effective at deactivating organic-based herbicides depending on the chemical and dosage.

- 3. Growing plants that are not susceptible** to the product or in such a way as to limit contact (e.g. growing on benches). Some plant lines may be able to tolerate the product and grow normally, whereas others are very susceptible and become unsaleable with exposure to very low doses. If required, only grow plants that can grow normally or modify the growing area such that plants do not contact the product. This could involve growing plants off the ground and ensuring that roots do not contact contaminated aggregate, media or soil.

It is not recommended to “wash away” herbicides as a method of decontamination as this promotes leaching the product into the environment.

SUMMARY

Weed management in nurseries is most effective when a combination of physical, cultural, and chemical strategies are maintained. Put in place hygiene and cultural strategies to prevent weeds from entering the nursery. Monitor all incoming stock for weeds (and other plant health issues), keep growing areas clean and free of organic matter and crop debris. Store growing media to ensure it remains free of weed seed and use preemergence herbicides where required. Weeds that occur in the nursery should not be allowed to seed and proliferate; schedule hand-weeding at regular intervals to break the lifecycle of weeds that are present. Apply postemergence herbicides mainly around non-crop areas of the nursery to reduce risk of weeds spreading to stock plants.

ADDITIONAL RESOURCES

[Understanding and managing nursery weeds](#)

[NC State Extension Weed management in nurseries](#)

[Weed control in container crops](#)

[UMass Extension Checklist weed management](#)

[Rethinking weed control in the nursery](#)

[A review of weed control practices in container nurseries](#)

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TABLE 1. HERBICIDES REGISTERED IN AUSTRALIA FOR WEED CONTROL IN PRODUCTION NURSERIES.

Not all products will be suitable for all businesses, and products from additional active ingredients may be used for specific crop plants that are not included. It is always recommended to check each label or minor use permit to ensure that it covers your situation. Product names listed here are examples and not endorsements of that product.

MoA GROUP	ACTIVE INGREDIENT	PRODUCT NAME	SELECTIVITY	NOTES
A	Clethodim	Havoc Plus 360	Postemergence graminicide.	Rapidly degraded by microbes and sunlight. Soil half-life 3 days.
A	Fluazifop-P	Surefire Cannonade	Postemergence graminicide.	May be applied over the top of many ornamentals in containers and in greenhouses. Half-life in soil less than one week.
A	Sethoxydim	Sertin 186EC Selective	Postemergence graminicide.	Readily degraded and potentially leachable. Soil half-life 5–25 days.
C	Simazine	FarmOz Simazine	Preemergence herbicide. Controls some annual broadleaf weeds.	Minor permit 84951. Not recommended for use where leaching potential is high. Soil half-life about 60 days.
D	Chlorthal dimethyl	Dacthal	Preemergence herbicide. Controls grasses and broadleaf weeds.	Soil half-life 14–100 days.
D	Oryzalin	Embargo Surflan	Dinitroaniline preemergence herbicide. Controls annual grasses and some broadleaf weeds.	Little volatility or photodegradation. Can be used in containers. Most soluble and leachable of the dinitroaniline herbicides. Soil half-life about 20 days.
D	Prodiamine	Barricade	Dinitroaniline preemergence herbicide. Controls grasses and some annual broadleaf weeds.	Minor permit 84303. Observed to be safe for container plants as it is not readily leached. Not suitable for use on surfaces. Soil half-life 12-30 days.
D+G	Oryzalin + Oxyfluorfen	Rout Vault	Dinitroaniline preemergence herbicide that controls grassy and broadleaf weeds.	Better suited to woody plants, can adversely affect herbaceous plants. Avoid contact with foliage when applying to pot surface.
D+K	Pendimethalin + Dimethenamid-P	Podium Freehand	Dinitroaniline preemergence herbicide, controls grasses and some broadleaf weeds.	Suitable for container use, not suitable for use on surfaces or in enclosed structures. Do not use in propagation or liner production. Soil half-life pendimethalin about 40 days, dimethenamid-P 45 days.
G	Oxyfluorfen	Goal GoalTender	Preemergence herbicide with some postemergence activity (can kill weeds less than 10cm tall). Controls broadleaf weeds, only effective against certain annual grasses.	Minor permit 84951. Registered for woody ornamentals and select food crops. Not suitable for use on surfaces. Susceptible to photodegradation. Soil half-life 30–40 days.
G	Oxadiazon	Ronstar Turf and Ornamental	Preemergence herbicide. Controls most broadleaf and grassy weeds, however when used alone does not control some weeds such as chickweed and pearlwort.	Can adversely affect herbaceous plants. Best for potted and field grown woody ornamentals. Avoid contact with foliage when applying to pot surface. Not suitable for use on surfaces. Soil half-life 3–6 months.
L	Diquat + Paraquat	Spray.Seed 250 Herbicide	Postemergence non-selective contact action herbicide.	Minor permit 84951. Avoid spray drift, can cause significant damage to plants. Suitable for use around nursery stock and on surfaces. Diquat and paraquat half-life over 1000 days in soil.
M	Glyphosate	Roundup	Postemergence non-selective systemic action herbicide.	Minor permit 84951. Use only in non-crop areas for broad spectrum control of weeds. Reports of horseweed resistance. Soil half-life about 47 days.
N	Glufosinate-ammonium	Basta Finale	Postemergence non-selective contact herbicide.	Minor permit 84951. Half-life in soil 7–20 days.
O	Dichlobenil	Casaron 4G	Preemergence non-selective herbicide.	Not suitable for use in enclosed structures, highly volatile. Soil half-life 1–6 months.

MoA GROUP	ACTIVE INGREDIENT	PRODUCT NAME	SELECTIVITY	NOTES
O	Indaziflam	Specticle	Preemergence herbicide, selective against broadleaf weeds and certain grasses.	Use only in non-crop areas for broad spectrum control of weeds. Soil half-life 150 days.
O	Isoxaben	Gallery	Preemergence herbicide, selective against broadleaf weeds.	Use only in non-crop areas. Soil half-life 100 days.
Z	Acetic acid	Richgro Beat-a-Weed Contact Organics Weed Terminator	Organic postemergence non-selective contact herbicide.	May require repeat applications. Recommended to use on surfaces only.
Z	Nonanoic acid	Eureka! Organic Nonanoic Acid Apparent Alternative Herbicide	Organic postemergence non-selective contact herbicide.	May require repeat applications. Recommended to use on surfaces only.