Managing Liverworts in Production Nurseries

Prevention and control of liverwort outbreaks promotes healthier plants and lowers subsequent costs of uncontrolled infestations, which can be substantial. Outbreaks also increase costs associated with hand weeding, herbicides, fertiliser applications and can cause plants to be unsaleable. This resource provides detailed information on liverwort biology and management for production nurseries. A range of preventative, cultural management practices are recommended including monitoring all incoming stock, hygiene practices and irrigation and fertiliser management. These actions can substantially reduce liverwort populations. Pre- and postemergence herbicides for use against liverwort in production nurseries are listed and discussed, noting those available in protected cropping, outdoors growing areas and in non-crop areas. Overall, successful management of liverwort relies on putting in place many actions; reliance on any one method is unlikely to be effective.

INTRODUCTION

Liverworts are a common weed in greenhouses and production nurseries. They are a simple form of photosynthetic plant that lack true roots, stems and leaves. Water and nutrients are absorbed by the vegetative organs of the plant. Propagation can occur both vegetatively, or sexually via sporulation. Spores can be spread in the air or by water droplets, and therefore potentially infest recycled irrigation water and uncovered stored potting mix. Liverwort spores can survive for over a year.

There are approximately 9,000 species of liverwort, however *Marchantia polymorpha* is the most common species observed in production nurseries. Liverworts spread very easily and can be difficult to control as they thrive under conditions that are favourable for container plants in production nurseries. Once an infestation occurs, appropriate physical, cultural and chemical control practices can help prevent liverworts from spreading further. It is difficult to completely eradicate liverworts once established at a premises unless drastic measures are taken. For this reason, prevention is critical.

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IMPACT

A liverwort infestation causes a range of problems that can negatively impact container plants. Liverworts increase overall nursery demand for water and fertiliser. Liverworts limit water availability to the plant in two ways. First, they use up water reducing moisture in the container. Second, they thrive in high water environments and are naturally water repellent, thus limiting the amount of water that gets into the media during irrigation. The problem becomes acute when liverworts cover the surface of container and may lead to irrigation scheduling problems, as infested versus un-infested containers have different water requirements.

Similarly, liverworts use nutrients present in the media more quickly than would otherwise occur. They thrive in a high nutrient environment and can increase rapidly with fertigation. In some instances liverworts can smother young seedlings and cause plant death. Reduced nutrient and water availability may lead to poor and uneven growth across the crop.

In addition, control of liverworts increases the need for herbicide usage, increasing management costs and may cause phytotoxicity. The appearance of pots infested with liverworts, or dead liverworts from chemical control measures, reduces the saleability of the crop. Hand-weeding of living or dead liverworts is costly, tedious, leads to loss of potting mix and top-dressed fertiliser, and may injure plants during removal procedures. Unfortunately, some liverworts inevitably remain following hand-weeding and can even be spread during the process.

Liverworts can provide shelter and an overwintering space for other pests, such as fungus gnats, snails and slugs. Fungus gnats are another significant pest for growers, as larvae can cause seedling damage, and both larvae and adults may spread diseases.

IMPACT OF LIVERWORTS

- Limits water and nutrient uptake of nursery plants
- Reduced saleability due to poor plant growth and visual appeal
- May smother small plants
- Significant costs of managing liverworts (e.g. herbicide and weeding costs)
- Provides shelter for pests and diseases

GENERAL BIOLOGY

In nature, liverworts are found primarily in areas that are moist and humid throughout the year, particularly those with high nutritional availability. Liverworts are not found in areas that are dry for extended periods of time, due to their poor ability to store water. They also require water for reproduction.

Liverworts have no true leaves or roots but have structures that have similar function. The irregular, flat and glossy green structures, that are similar to leaves, are called thalli (singular thallus). The upper surface of thalli are photosynthetic, and can overlap and make up the majority of the green matt that can cover the surface of containers. A thallus can be about 2–8cm long, 1–8cm wide and up to 1.5mm thick. On the lower surface, liverworts have rhizoids (instead of true roots), which are unicellular hair like structures that anchor the liverwort to the substrate. Both the thallus and rhizoids absorb water and nutrients directly.

Probably the most important form of liverwort reproduction in nurseries and greenhouses is clonal reproduction. Thalli produce gemma cups that grow into bowl/cup-shaped structures about 3–4mm in diameter. Each cup produces disk-shaped gemmae and can hold a hundred or more gemmae at any one time. These can be distributed via splashing water droplets (rain or irrigation) and may grow into a clone of the mother plant. Gemma dispersal has been documented to occur up to 1.6 metres. This clonal reproduction allows liverwort colonies to spread rapidly. Vegetative reproduction can also occur via fragmentation of small sections of thalli growing into new individuals. Therefore, liverworts can persist if hand-weeding does not remove the entire liverwort plant and aids their spread if small pieces of thalli are transported to new areas (e.g. via hands or clothing).

Liverwort with gemmae cups. Image courtesy of Joe Neal, N.C. State Univ.

Close up of gemmae discs in cups. Image courtesy of Steve Tjosvold, University of California Cooperative Extension.

Liverworts also reproduce sexually. Individual plants are either male or female and their reproductive organs are umbrella-like stalked structures borne on top of the thallus. Male organs (antheridia) and female organs (archegoniophores) are positioned at the top of the stalks. Sperm cells travel to the eggs only when water is present on the thallus. Each female structure can develop thousands of microscopic spores. Once fertilised and mature, spores are dispersed by wind or water, and germinate within several days on moist substrate under suitable growing conditions. Young thalli develop within a week from both spores and gemmae.

Pot infested with liverwort. Tall stalked structures are female reproductive structures, and shorter flat umbrella structures are male. Image courtesy of Steve Tjosvold, University of California Cooperative Extension.

Both sexual and clonal reproduction can occur simultaneously. In nature, liverworts will continuously reproduce clonally in cooler regions from early spring to late autumn. The optimum temperature for vegetative growth is 18–22°C, common inside greenhouses and nurseries particularly in southern regions of Australia. Reproductive organs are produced at slightly cooler temperatures, between 10–15°C. Consequently, liverworts are typically weed problems in cooler regions, but can become prevalent in warmer areas during their cooler months.

CONTROL AND MANAGEMENT

An effective liverwort management program integrates cultural and physical prevention measures and chemical control. However, what works in one nursery may not necessarily be effective for all, therefore tailor management strategies to suit your needs. Appropriate control is dependent on where the infestation is located in the nursery, such as walkways, benches, drains or in containers.

Minor infestations can spread incredibly fast and are difficult to completely eradicate due to the persistence and spread of gemmae and microscopic-sized spores. In particular, airborne spores are impossible to completely exclude from the nursery, but actions taken can reduce risk of infestations. Keeping up with prevention and control measures is imperative, or liverworts will persist and may spread through the nursery and down the supply chain.

FAVOURABLE CONDITIONS

The first step in liverwort control and management is understanding the conditions in which they thrive. As detailed above, liverworts prefer cool temperatures, low UV light, high humidity, moist substrates, high nitrogen (between 75–250ppm) and phosphorus availability. These factors are often present in production nurseries, which is why liverworts make efficient nursery pests. Overall, therefore, nurseries in cool climates with growing areas having high water and nutrient availability favour liverworts greatly.

PREVENTION AND CULTURAL CONTROL

The best way to stop a liverwort outbreak is to prevent their entry and to make sure growing conditions are least favourable to liverwort growth.

Quarantine and inspect all new stock. Keep new stock in a designated quarantine area for a set period of time to observe. Isolate any that are contaminated with liverwort. If it is present in new stock, contact your supplier to determine how they have managed liverwort infestations. This can affect the actions you subsequently take. For example, if the supplier only completed a hand weed prior to dispatch, you can expect there will be plenty of liverwort developing in that stock in the future.

Do not overwater plants. Liverworts thrive in wet conditions, due to the absolute requirement of water for growth and reproduction. Allow the surface of the growing medium to dry between irrigation cycles, if the crop can tolerate it. Consider if a subirrigation system, such as drip or micro irrigation, could suit your business. Subirrigation has been shown to greatly reduce liverwort establishment. Also allow for sufficient drainage of containers. Raised benches and/or coarse gravel improves water drainage by preventing water pooling under pots.

Manage your growing areas. Avoid actions that spill growing media into the growing area and walkways. Remove growing media and organic matter from these area regularly.

Containers infested with liverworts. Image by DAF.

Do not over fertilise. Liverworts thrive and reproduce rapidly in the presence of high nitrate and phosphate. Top-dressing liquid, granular or slow-release fertiliser encourages liverwort growth and reproduction greatly. Incorporate controlled release fertiliser into growing media or dibble to reduce the amount of fertiliser present on the surface.

Top dressing containers with slow release iron sulfate and/or copper sulfate may be an option, as they fertilise plants and provide some reduction in liverwort surface colonisation. Similarly, zinc sulfate or zinc chloride fertilisers may also retard liverwort growth. However, be aware that overuse of both copper and zinc products are potentially phytotoxic, and some fertilisers may affect media pH. Organic acidic smoke extracts products have also been used as a fertiliser on some ornamental crops with demonstrated pre- and postemergence activity against liverworts and mosses. It is recommended to trial products on a small batch of plants to establish their efficacy at your business prior to widespread usage. Such trials should have both treated and untreated plants of the same variety and size.

A combined reduction in irrigation frequency and amending fertiliser applications have been shown to reduce liverwort infestations by as much as 80%. Some nurseries have almost eliminated liverwort just by changing irrigation practices and spot-treating wet walkways and under benches within production areas.

Consider your growing media composition. If possible, increase the air-filled porosity of growing media to increase drainage. 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. Regardless, it is recommended to use a media that dries quickly on the surface, but also retains moisture lower in the pot.

Growing media storage. Store media to prevent contamination with liverwort spores, which can be translocated over long distances via wind. Storing media undercover on a clean sealed surface prevents contamination from weeds and pathogens, and reduces exposure to sunlight and rain, thus reducing humidity and heat.

Use surface mulches. Mulches effective against liverworts have the following properties: little to no available nutrients, quick drying post irrigation, and resist decomposition. There are many types of mulch currently used to top-dress containers, such as rice hulls, pine bark, nut shells, cocoa hulls and pumice. These mulches may, however, reduce

saleability of plants if left remaining on the growing media surface. One study demonstrated that 1.25–2.5cm of rice hulls provided almost 100% liverwort control for 8 weeks in large containers. Even 0.5cm of rice hulls in smaller containers provided some suppression of liverworts. Several other mulches, such as cocoa hulls, have also been used to suppress liverwort in containers. Even though the cost of mulches may be relatively high, they may still be cost effective given the limited number of preemergence herbicides available.

Sanitise or treat irrigation water. Liverwort spores may persist in recycled irrigation water, and there is a possibility that liverwort spores may be wind-blown into water storages. Disinfestation treatments use chemical (chlorination, bromination, chlorine dioxide or ozone) and non-chemical methods (heat, ultra-filtration, UV radiation or slow sand filtration). However, there have been no studies investigating the efficacy of common water disinfestation systems killing liverwort spores, and in some overseas nurseries liverworts have successfully germinated from samples of treated recycled nursery water. Testing irrigation water for viable spores during an outbreak may indicate the effectiveness of your sanitation system.

Disinfest growing surfaces and tools between crops. Disinfest used pots with heat or use new, clean pots. Store new and clean containers appropriately to avoid contamination. Ensure horticultural tools are appropriately sanitised. Disinfest growing areas between crops applying an appropriate disinfestant, herbicide (if required) and remove organic matter. Nursery hygiene is important for weed control and management of pests and diseases.

Liverworts growing on weed matt in a growing area may spread into containers and should be managed vigorously. Photo by J. Neal, N.C. State Univ..

Hand weeding and removing infested containers. Hand weeding liverworts may be problematic and costly. Spores and gemmae are easily dispersed and removing liverworts from the container surface will also remove a measurable amount of potting media. However, if liverwort pressure is high, hand weeding followed by herbicide application is an appropriate first step in controlling an infestation. Note that dead liverworts from chemical use on a container surface are more unsightly than a living infestation. Consider completely removing infested containers from the site to reduce spore load. This is particularly useful if the crop is sensitive to herbicides.

Modify environmental conditions. As stated above, liverworts require light and moisture to thrive. It is possible to modify the plant growing conditions to make the area less favourable. For example, liverworts are a problem year-round in greenhouses or structures that maintain high humidity with excess water available. Incorporating appropriate plant spacing and increased ventilation will improve air circulation and help reduce humidity levels. Hot summer temperatures (particularly if it is dry) can also be used to assist in breaking the lifecycle if containers can be allowed to dry for periods of time. Lastly, liverworts require light to photosynthesise just like any plant, and therefore fail to thrive if the crop's canopy shades the growing media surface completely. This option is probably only helpful for specific crops.

CHEMICAL CONTROL

Liverwort cannot be controlled with herbicides alone. The higher the infestation in the container, the lower the efficacy of the chemical. Use as many cultural and preventative actions as possible to reduce liverwort pressure. Use pre- and postemergence herbicides strategically, using an integrated approach. Preemergence herbicides are particularly important to assist in preventing liverwort infestations. Postemergence herbicides can be used to assist in breaking the lifecycle, eradicating small outbreaks. There is no evidence of liverwort resistance to herbicides.

There are relatively few herbicides specifically registered for liverwort control in production nurseries in Australia (Table 1) with varying levels of efficacy. Although thalli may die, in most cases spores and gemmae survive to recolonise growing media if environmental conditions are suitable. The level of infestation, stages present, and nursery conditions will all influence the efficacy of herbicide applications. Also consider the impact of dead liverworts on the surface of potting media; it can be more unsightly than a living infestation. Therefore, proactive management is required to sell products without

Cuttings trays infested with liverwort and moss (left), and trays successfully treated with preemergence herbicide (right). Image by DAF.

liverworts present. This may involve physical removal of liverworts in combination with herbicide applications.

Studies have shown that acetic acid products used as postemergence herbicides can control liverwort by around 50%, but is not long-lasting. However, the low pH of acetic acid can cause phototoxicity and alter the pH of the growing substrate. One study determined that 1.25% was the optimum concentration that killed liverwort, with minimal to no phytotoxicity. Regardless, acetic acid herbicides are only registered for use on surfaces, not containerised nursery stock.

Products used against mosses and algae may also be effective postemergence chemicals against liverwort (where mosses and liverworts cooccur) and may be used in enclosed structures and in pots. It should be noted that glyphosate offers minimal to no liverwort control.

There may be other herbicides labelled for other weeds that are effective against liverworts but are not specifically registered for this purpose in Australia (e.g. products with actives oxyfluorfen (sometimes with oryzalin), oxadiazon, prodiamine and diquat). For this reason, it can be worth considering incidental liverwort management within a framework of overall weed management at your nursery. Further 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.

SUMMARY

If an ongoing liverwort infestation is occurring in your nursery, the combination of reducing irrigation frequency and lowering excess nutrient availability on the surface of the pot is very effective. This will greatly reduce the ability of liverwort to grow and reproduce. Surface coverings or mulches will also successfully suppress outbreaks. Ensure that liverworts in peripheral areas (benches, walkways, drainage ditches etc.) are spot-treated with appropriate chemical products. Liverwort infestations in containers can be killed by chemicals and/or removed by hand-weeding, but be aware of the prevalence of remaining gemmae and spores that can continue the liverwort cycle. Follow up herbicide treatments are likely to be required following initial hand-weeding and herbicide application. Clean and disinfect empty greenhouses, pots and tools between crop cycles with the aim of reducing spore-load. Using these techniques liverwort can be managed effectively.

ADDITIONAL RESOURCES

- Understanding and managing nursery weeds
- Disinfestation protocols for equipment used in the nursery industry
- Biology and management of liverwort in ornamental crop production
- Identification and management of liverwort in greenhouses
- Identifying and managing liverwort in nurseries and greenhouses

TABLE 1. CHEMICALS REGISTERED FOR USE AGAINST LIVERWORTS IN AUSTRALIA IN THE NURSERY SECTOR.

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 trade names listed here are examples and not endorsements of that product.

ACTIVE INGREDIENT	TRADE NAMES	MoA GROUP[1]	NURSERY STOCK	SURFACES	NOTES
Acetic acid Acetic acid + hydrochloric acid	Richgro Beat-a-Weed Contact Organics Weed Terminator	Z	No	Yes	Organic contact herbicide. Postemergence. Non-selective damage to crop plants. Repeated applications may be required.
Nonanoic acid/ pelargonic acid	Eureka! Organic Nonanoic Acid Apparent Alternative Herbicide	Z	No	Yes	Organic contact herbicide. Postemergence. Can cause significant damage to plants. Repeated applications may be required.
Benzalkonium chloride	Yates Surrender Mosskiller	N/A	Yes	Yes	Algaecide, antimicrobial. Postemergence. Death of liverwort occurs within days. 50ml/L provides effective control[2].
Dichlorophen	Kendon Kendocide	N/A	Yes	Yes	Algaecide, antimicrobial. Postemergence. Liverworts turned brown within one week and were dead after one month post application dose of 2000ppm[3].
Pendimethalin + dimethanamid-P	Podium Freehand	D + K	Yes	No	Dinitroaniline preemergence herbicide. May be slow acting.

[1] Herbicide mode of action group.

[2] Bryophyte control with benzalkonium chloride.

[3] Control of liverwort growth with dichlorophen

This document was prepared by Joy Conroy, Andrew Manners and Sarah Dodd (Agri-Science Queensland, Department of Agriculture and Fisheries, Ecosciences Precinct, GPO Box 267, Brisbane QLD 4001) in 2020 and updated in 2021 as part of the nursery levy and Hort Innovation funded project Resourcing, supporting, and assessing biosecurity in nursery production (NY20000)