Controlling Liverworts and Moss in Nursery Production

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INTRODUCTION

Liverworts and mosses are persistent weeds that infest containers soon after successfully propagated plants are potted. The light, temperature, humidity, growing media, irrigation, and fertility regimes needed by newly potted plants are ideal conditions for liverwort growth. Often, liverworts can grow faster than the desired plants, smothering crops and profits. Transplanted tissue-cultured plantlets, fern sporlings, seedlings, and cuttings in trays, flats, and liner pots are the most susceptible to liverwort infestations. Changes in pesticide laws (especially for greenhouse use), unavailable chemical products, and changes in cultural routines of growers have all contributed to increased liverwort infestations. Strategies for getting this weed under control are needed. Mosses are often controlled using the same procedures used to control liverworts. The objective of this paper is to provide a starting point from which a grower can formulate a liverwort and moss control program.

What are Liverworts? Liverworts are small plants generally related to mosses and hornworts. They are identified by their mats of green thalli found growing on moist surfaces, such as growing media. Sometimes they are confused with fern gametophytes called prothallus. There are over 10,000 species of liverworts. Most liverworts infesting container-grown plants belong to the genus *Marchantia*, such as *M. polymorpha*. *Marchantia* are complex, thalloid liverworts, and are very adaptable. Most liverworts are mycorrhizal. *Gerronema marchantiae* has been identified as a fungus that forms mycorrhizae with *M. polymorpha*. Without the fungal symbiont, the ability of the liverwort to obtain water and minerals is restricted.

Why are Liverworts Considered Weeds by Nursery Growers? Liverworts growing on walkway surfaces are slippery, creating a safety hazard for employees and customers. Liverworts growing on benching, walls, or floors of the growing area (greenhouse, shadehouse, or outdoor container yard), or on the surface of container growing media, provide a home for fungus gnats, and food for slugs and snails. Liverwort thalli mat down the surface of the growing medium, slowing the entry of water applied during irrigation or rainfall. Liverworts absorb mineral fertilizers intended for use by crop plants. Customers avoid purchasing plants infested with liverworts. Finally, the cost of handweeding to remove liverworts renders many crops unprofitable, and may damage the roots of desired plants.

How do Liverworts Spread into Container Grown Plants? Liverworts propagate themselves in three ways. First, any portion of the prothallus that breaks off the main body can establish itself as a new colony (fragmentation). Second, *Marchantia* produce vegetative propagules called gemmae inside gemmae cups (gemmae cups look like suction cups on the upper surface of the thalli). Whenever water drops from rainfall or irrigation land inside a gemmae cup, the gemmae are scattered by splashing. Finally, *Marchantia* produce air-borne spores inside female fruiting bodies called archegonia (archegonia look like little umbrellas on top of stalks extended above the thalli). Wind can scatter the air-borne spores over great distances. It is the airborne spores of liverworts that usually infest container grown plants, with splashing of gemmae from gemmae cups adding to the infestation after they are established. Our studies do not indicate that liverwort propagules will build-up in recirculating/recycling irrigation systems. In greenhouses, infestations usually begin near doorways or outdoor vents, and then spread down wind toward exhaust fans. The mesh size of insect screening is not small enough to exclude liverwort spores, but may help by restricting spore movement into the greenhouse.

PREVENTING LIVERWORT INFESTATIONS

Since even dead liverwort thalli are unsightly, it is important to prevent liverwort infestations from getting established. An integrated combination of cultural and chemical controls are required. Using physical suppression techniques utilized will lower the risk of liverwort infestation.

Physical Suppression of Liverwort Establishment. Eliminate wet and weedy areas around the nursery. Install insect-exclusion screening around greenhouse vents and doorways. Wash and sanitize cuttings, especially lower leaf surfaces, before sticking. Wash and sanitize all greenhouse surfaces between crops. Products like EcoClear, Zero-Tol, and the quaternary ammonium products are very helpful during the sanitation process. Do not purchase liverwort-infested propagules, and remove any liverworts before potting. To reduce the spread of liverworts by splashing, reduce or eliminate overhead irrigation and mist. Using subirrigation and fog helps reduce the spread and establishment of liverwort colonies. Allow the surface of the growing medium to dry out between irrigation cycles. Keeping the surface of the growing medium loose rather than packing-in the plants during potting helps dry the top surface between irrigation cycles, and allows liverworts spores to be washed down into the darkness of the growing medium where they do not grow (spores require light to germinate). Use medium components that allow for rapid drying on the surface. Liverworts grow rapidly when nitrogen is available in the 75 to 250 ppm range. If your crop can be grown using less than 75 ppm N, you may be able to slow liverwort establishment.

Another physical technique is to apply a fast-drying mulch to the surface of the growing medium (Table 1). We have had good success using rice hulls, hazelnut shells (not crushed), and pumice. Other nurseries report good results using turkey grit and oyster shells. Mulches should completely cover the surface of the growing medium, should not blow away in the wind, and should dry rapidly between irrigation cycles. We have also tested geotextile discs placed on the surface of the growing medium. The discs prevented growth of liverwort, moss, and all other weeds when both sides of the fabric were treated with copper compounds (e.g., SpinOut™), but when the fabric was not treated, liverworts often grew on the soil surface underneath the disc. For some growers, slight changes in their irrigation and fertilization routines and the use of suppressive mulch have eliminated liverworts as a major weed in their nursery.

Table 1. Partial list of surface mulch products observed by nurserymen to slow the establishment of liverworts or moss in container-grown nursery crops. For best suppression of liverworts, mulches need to provide complete cover of the surface of the growing medium, and need to dry rapidly — avoid overwatering.

Material	Comments
calcined clay	fair to moderate suppression if you screen-out fines
cedar sawdust	moderate suppression
coarse sand (turkey grit)	moderate suppression
cocoa shells	good suppression; do not crush shells
corn gluten meal	fair to good suppression; supports growth of algae
crushed granite	moderate suppression
geotextile discs	liverwort grows under it
geotextile discs treated with copper	good suppression
hazelnut shells	good suppression; do not crush shells
oyster shells	good suppression; do not crush shells
perlite	fair suppression
pumice	moderate suppression
rice hulls	good suppression; kill rice seed before use

Chemical Suppression of Liverworts Using Surface Fertilization. Many of the products listed in Table 2 are fertilizers. Integrating these with physical techniques helps prevent liverwort establishment. The application of heavy metal fertilizers on the surface of the growing medium slows liverwort establishment and growth. Iron oxides (such as Granusol™) have been used successfully, compared with copper compounds, which provide only fair liverwort suppression. Zinc compounds are very effective, but have a higher risk of crop plant phytotoxicity. Some growers have used an alternating application of an acidifying fertilizer followed by a fertilizer with a basic reaction. The sudden changes in the pH at the surface of the growing medium helps prevent liverwort growth and establishment. Carefully monitor the pH of the medium when surface fertilization is being used.

Chemical Suppression of Liverworts Using Pre-emergent Herbicides. Many of the products listed in Table 2 are pre-emergent herbicides. All of the herbicides have some suppressive activity against liverworts. We have had the best success using liquid formulations of oxadiazon or oryzalin. Many of these pre-emergent herbicides will also contribute (slowly) to the eradication of existing liverwort populations. Be sure to test the herbicides for phytotoxicity before applying it to your entire crop. Besides leaf burn, defoliation, and other obvious signs of phytotoxicity, watch for damage to roots, poor lateral branching, damage to stems at the soil-line, and overall poor plant vigor. Combining physical techniques, surface iron or copper fertilizer applications, and pre-emergent herbicides has nearly eliminated liverworts in several nurseries.

Table 2. Partial list of chemical products observed by nurserymen to have pre- or post-emergence activity against liverworts in container-grown nursery crops. Test application rates listed on product labels, unless otherwise suggested under comments. Comply with all laws regulating product use in your locality. Best liverwort control is obtained using an integrated rotation of products that work at your location.

Sample chemical name	Brand names	Application timing	Comments
acetic acid (20%)	Vinegar	post-emergence	use a 10% to 75% solution; bad odor; stains roots brown; burns or defoliates soft growth; best on dormant plants; inconsistent
ammonia	Ammonia	post-emergence	3 parts ammonia to 1 part water
benzylkonium chloride	MossOff, Paramos, Surrender	post-emergence	not currently available in the United States
captan	Captan	pre-emergence	good suppression as pre-emergent
chlorothalonil	Daconil, Bravo, Thalonil	pre-emergence	fair suppression as pre-emergent
chloroxuron	Tenoran	pre-/post-emergence	do not apply to *Rhododendron* or *Erica*
cinnamic aldehyde	Cinnacure	pre-/post-emergence	seasonally variable; mild risk of phytotoxicity; limited availability in the United States
copper ammonium carbonate	Croptex, Fungex,	pre-/post-emergence	inconsistent; fair suppression as pre-emergent
copper hydroxide	Kocide, Blue Shield	pre-/post-emergence	inconsistent; fair suppression as pre-emergent
copper oxychloride	Ashlade SMC, COC WP, Cuprokylt	pre-/post-emergence	inconsistent; fair suppression as pre-emergent
copper sulfate	Citriplex, Phyton-27, MicroCop, Top-Cop	pre-/post-emergence	inconsistent; fair suppression as pre-emergent
copper-sulfur-lime	Bordeaux, WetCol 3	pre-/post-emergence	inconsistent; fair suppression as pre-emergent

cresylic acid	Armillatox, Bray's emulsion	post-emergence	inconsistent; not currently available in the United States
dichlobenil	Casoron, Fydulan, Norosac	pre-emergence	fair suppression as pre-emergent
dichlorophen	Biomoss Killer, Debco Professional Liverwort and Moss Control, Enforcer, Fungo, Mostox, Panacide, Halophen	post-emergence	not currently available in the United States
dicofol + acephate	Kelthane + Orthene mixed	post-emergence	one report of good post-emergent control
diflufenican and trifluralin	Ardent	pre-/post-emergence	for walkways and under benches; not available in the United States
dimethyl tetrachloro-phthalate (DCPA)	Dacthal	pre-/post-emergence	good suppression as pre-emergent
dinoseb acetate	Aretit	post-emergence	not available in the United States
dodine acetate	Cyprex, Melprex	post-emergence	no longer available in the United States
ethanoic acid (acetic acid + citric acid)	EcoClear	post-emergence	use like vinegar
ethylene bisdithio-carbamate + Mn and Zn	Mancozeb, Maneb Manzate, Fore, Dithane, Duosan, Karamate, Penncozeb, Ridomil, Zyban, Pace	pre-/post-emergence	good suppression as a pre-emergent; a favorite of many U.S. growers
fatty acids	DeMoss, M-Pede, Safer's Soap, Off-Shoot-O insecticidal soap	post-emergence	moderate risk of phytotoxicity; inconsistent; low temperatures reduce activity
hydrogen dioxide + peroxyacetic acid	Zero-Tolerance	pre-/post-emergence	only one test report; insufficient data

iodophor	Vanodine	pre-/post-emergence	only one test report; fair to good suppression
iron (controlled-release)	Controlled-release fertilizers	pre-emergence	fair to moderate suppression as a pre-emergent
iron oxide	GU49, Granusol	pre-/post-emergence	try 200 g per 10 liters; monitor pH
iron sulfate	lawn sand (many brands), Maxicrop Mosskiller, Turf Tonic	pre-/post-emergence	rate varies with Fe percent in product; use only once; may stain stems; monitor pH
isoxaben	Flexidor, Gallery, Bray's emulsion KnotOut, SnapShot	pre-emergence	fair to good suppression as a pre-emergent
lactophen	Cobra	pre-/post-emergence	unknown phytotoxicity; low volatility; good experimental results; no use label in the United States for nursery crops
lenacil	Venzar, Vizor	pre-emergence	fair to good suppression as pre-emergent; fair risk of phytotoxicity
oryzalin	Surflan, Rout	pre-emergence	fair to good suppression as a pre-emergent
oxadiazon	Ronstar, Regal O-O	pre-emergence	fair to very-good suppression as a pre-emergent
oxyfluorfen	Goal, OHII, Rout	pre-emergence	fair suppression as a pre-emergent
pelargonic acid	Scythe	post-emergence	high risk of phytotoxicity; low temperatures reduce activity
quaternary ammonium compounds and *ammonium chlorides*	Bioguard, Consan, Physan, Triathlon, Algaen-X, GreenShield	post-emergence	high risk of phytotoxicity
quinoclamin	Mogeton	pre-/post-emergence	best as pre-emergent; some risk of phytotoxicity; not currently available in the United States; a favorite of many European growers
simazine	Princep	pre-/post-emergence	control is slow; moderate risk of phytotoxicity
soaps	dishwasher soap, laundry soap	pre-/post-emergence	moderate risk of phytotoxicity; inconsistent

sodium carbonate peroxyhydrate + sodium carbonate	Terra-Care	pre-/post-emergence	moderate suppression; fair risk of phytotoxicity
sodium hypochlorite (10%)	bleach	post-emergence	high risk of phytotoxicity
sodium metaborate + boron trioxide	BareSpot	pre-/post-emergence	very high risk of phytotoxicity; avoid contact with desired plants or surfaces near desired plants
thiram	Thiram, Thianosan, Tersan, Thylate, Spothrete	pre-/post-emergence	mild risk of phytotoxicity; often used by growers in the United States
zinc chloride	zinc chloride fertilizers	pre-/post-emergence	moderate to high risk of phytotoxicity; good control as pre- or post-emergent
zinc sulfate	zinc sulfate fertilizers	pre-/post-emergence	moderate to high risk of phytotoxicity; good control as pre- or post-emergent

Table 3. Influence of the concentration of cinnamic aldehyde (Cinnacure™) applied days after treatment (DAT), and season of treatment on the percentage of growing medium surface covered with liverworts and the percentage of *Rhododendron* 'Jean Marie Montague' leaves burned.

Application date	DAT	Concentration applied %	Percentage of medium surface covered	Percentage of burned leaves[1]
November 17	3	0.0	38	0
		0.25	17	0
		0.5	8	0
		1.0	0	0
November 17	10	0.0	43	0
		0.25	10	0
		0.5	2	0
		1.0	0	0
November 17	30	0.0	52	0
		0.25	14	0
		0.5	5	0
		1.0	1	0
February 21	3	0.0	32	0
		0.3	26	0
		0.6	5	0
		0.9	0	4
February 21	10	0.0	36	0
		0.3	14	0
		0.6	2	22
		0.9	0	59
February 21	30	0.0	35	0
		0.3	15	2
		0.6	2	21
		0.9	0	57

[1]Phytotoxicity symptoms were leaf burn (desiccation) at locations where the cinnamic aldehyde formed puddles on the leaf surface after application. Inclusion of a non-ionic surfactant to help prevent puddling may help reduce the risk of leaf burn.

Eradication of Existing Liverwort Populations. Eradication of existing liverwort infestations is difficult, and some customers consider dead liverwort bodies more unsightly than live ones. Many products listed in Table 2 include a label specifying their use for post-emergence liverwort control. The risk of damage to your crops when using these products is avoided if liverwort infestations can be prevented. It is important to eliminate established liverwort colonies as soon as possible.

We have recently tested several products, including cinnamic aldehyde (Cinnacure™) and benzylkonium chloride. Effective rates and phytotoxicity of cinnamic aldehyde varied among seasons (see Table 3), but growers testing this product feel it will be a useful tool. Higher rates are needed under cool, moist conditions. We have tested benzylkonium chloride at rates from 1000 to 10,000 ppm, with the 5000 ppm rate providing the most consistent control. However, each cultivar needs to be tested for phytotoxicity. Quinoclamin, cresylic acid, and lactophen may prove to be useful tools in the future.

Some of the products listed in Table 2 that are not fertilizers or herbicides do have a suppressive effect on liverwort populations (such as the combination of dicofol and acephate). Many of these are fungicides, which may help eradicate liverworts by killing the fungal symbiont associated with the liverwort thalli. If you have a need for fungal or insect control, you may be able to carefully select the pesticides that will help you control any liverwort infestations as you seek to control your other pests.

Biocontrol of Liverworts? A couple of nurseries in Washington state have noticed a fungal organism feeding on liverworts and algae on the surface of their containers during the winter cycle. This potential biocontrol agent is very sensitive to dry air, heat, and bright light, and we have not been able to culture it on artificial media. One preliminary evaluation suggested that the fungus is a species of *Fusidium* (a type of fungi commonly found in soils), but this report has not been confirmed.

CONCLUSION

A balanced attack, focusing on prevention, is required to eliminate liverworts and mosses from the growing environment. Since more spores are always arriving on the wind, vigilance is important. Effective management of physical controls, surface fertilizers, pre-emergent herbicides, and post-emergent controls is needed for complete control of liverwort and moss infestations.