

Using Essential Oils to Control Moss and Liverwort in Containers

Nabil Khadduri

Nabil Khadduri is Grower, Meridian Seed Orchard (formerly Nursery Scientist, Webster Nursery), Washington Department of Natural Resources, PO Box 47017, Olympia, WA 98504; Tel: 360.789.9483; E-mail: nabil.khadduri@dnr.wa.gov

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Abstract: Liverwort and moss are economically significant weeds across a range of US container production sites, including forest seedling greenhouse culture in the Pacific Northwest. We have demonstrated the effectiveness of essential oils, or distilled plant extracts, in controlling liverwort and moss container weeds over three seasons of trials. When applied at the appropriate concentration and volumes, essential oils act as an effective contact herbicide. There is little or no residual, and under heavy pressure, liverwort and moss can re-establish within 2 weeks of knockdown. The applicator must pay close attention to method and application rates to successfully control weeds while avoiding crop damage, such as leaf or needle burn. Leaf wilt following the first drying cycle has occasionally been observed, with root damage suspected but not confirmed. This paper summarizes integrated pest management practices to limit the invasion and spread of liverwort and moss in containers, details post-emergent trial results of directed-spray and over-the-crop herbicide applications, suggests guidelines for species and stocktype stages, and provides a checklist of procedures when applying essential oils.

Keywords: essential oils, liverwort, moss

Liverwort and Moss in Container Nurseries

A national survey of container and nursery growers and extension specialists ranked liverwort as the number two weed in horticultural production (IR-4 2009). This survey also identified liverwort, moss, and algae as the third largest “group” of weeds in container production, trailing only broadleaf plants and sedges. Liverwort and moss reduce crop growth and value by outcompeting crops for water and nutrients and by providing habitat and encouraging the development of fungus gnat populations. In the Pacific Northwest (and throughout much of the US), *Marchantia* liverwort (*Marchantia polymorpha*) is the liverwort best adapted to container culture, while silver-thread moss (*Bryum argenteum*) is the most likely moss to infest greenhouses.

Liverwort and moss are lower plants, meaning they lack a vascular system. They are the cockroaches of the plant world, with liverwort thought to be the first group of plants to make the transition from blue-green algae to successful land colonization. Liverwort and moss have several reproductive strategies, including asexual propagation through simple division as well as the unique ability of liverwort to develop gemmae cups. These cups fill with gemmae, small plant fragments, which can splash up to a meter away from the mother plant when hit at the right angle with a drop of water (Figure 1). Liverwort and moss also reproduce sexually, developing spore-releasing capsules.



Figure 1. *Marchantia* liverwort (*Marchantia polymorpha*) can develop gemmae cups. The gemmae fragments within can splash up to 1 m (3 ft) away from original plant.

Pre-crop Sanitation

Spore-release of liverwort and moss is widespread, so the primary goal of a nursery manager should be to kill spores between crops. Pre-crop sanitation may include the use of pressure washing to remove bulk debris and follow-up with a chemical treatment; any chemical treatment is always more effective with thorough pre-washing. Chemical treatments that are commonly used to reduce spore loads of liverwort, moss, and algae are quaternary ammonium chlorides, sold as products such as GreenShield® (Whitmire Micro-Gen Research Laboratories, St Louis, MO), Physan 20™ (Maril Products Incorporated, Tustin, CA), and Triathlon® (OHP Incorporated, Mainland, PA). Other chemical treatments include hydrogen dioxide, chlorine dioxide, and chlorine bleach (Smith 2007).

Forest seedlings are commonly grown in Styroblock™ containers (Beaver Plastics, Acheson, Alberta); along with other container styles, these may be a vector for liverwort and moss spore contamination from one crop to the next. Probably the most effective treatment to sterilize blocks, particularly for older blocks where old plant debris is very difficult to physically remove, is steam cleaning. Steam cleaning setups are expensive, but alternatives exist. At Washington Department of Natural Resources Webster Nursery (Olympia, WA), we use a hot-water dip tank to clean blocks. We run temperatures at 77 to 82 °C (170 to

180 °F) for up to a minute, that is, just short of “warping” the blocks.

Additional pre-crop sanitation includes removal of any existing liverwort and moss adjacent to greenhouses. Baking soda, liberally sprinkled on liverwort in non-crop areas (complete coverage is not necessary), acts as an effective contact herbicide for initial eradication. Combinations of weed barrier and mulch, weed barrier alone, or pre-emergent herbicides such as flumioxazin or dimethenamid-P may be applied to limit liverwort and moss growth.

Sanitation During Propagation

Once a greenhouse crop cycle begins, the best liverwort and moss prevention strategy is to kill any spores that float into the greenhouse before they make it past the germination stage. Applying ZeroTol™ (BioSafe Systems, Glastonbury, CT) (hydrogen dioxide, peroxyacetic acid, and stabilizers) at 1:450 as a post-rinse following each irrigation can successfully reduce spore loads (Thompson 2008). Another spore-killing strategy is to apply a constant ultra-low dose chlorine or copper treatment to kill spores through an in-line system.

Water Management

Greenhouse cultural practices are paramount to liverwort and moss control, with particular emphasis on water management; these weeds thrive in the presence of moisture. Choose mulches, such as screened grit, that are standardized in size, smooth-surfaced, and therefore drain well. Uniformly cover soil medium at time of propagation, as exposed surfaces will become infested quicker.

Try to be a “dry” grower. To the extent possible, water by plant needs rather than human convenience. Up-front costs spent on determining when a crop actually needs irrigation will be rewarded with less water usage, lower pest pressure, and ultimately a higher quality crop. Once a decision to irrigate has been made, consider expediting crop drying with a spreader that breaks down water-surface tension, such as Sylgard® 309 or R-11® (Wilbur-Ellis, Fresno, CA). This practice is especially called for in late-day irrigations or irrigations in overcast weather. Use horizontal airflow fans in opposing patterns to break up boundary layers and monitor and reduce excessive relative humidity where possible. Again, liverwort and moss need moisture to thrive, in almost all cases more than the crop you are actually trying to grow. Starve them of excess moisture as a basic prevention technique.

Nutrient Management

Liverwort and moss love nutrients and, like many plants, thrive in nitrogen and phosphorus-rich environments. Growers may have a tendency to apply excessive amounts of fertilizer (“luxury consumption”) to push seedlings to size simply because stock that does not meet minimum morphological specifications is less marketable. Seedling nutrient analysis can help a grower differentiate between hidden hunger, optimal growth, and luxury consumption, thereby targeting nutrient applications at levels that do not excessively stimulate liverwort and moss growth.

Since liverwort and moss are shallow-rooted (not really having roots at all, but rather root-like structures called rhizoids), they thrive in environments where nutrients are surface applied. Limiting surface-applied nutrient application generally means decreasing fertigation, the practice of applying fertilizer through the irrigation system. When a grower fertigates, they are applying nutrients to the soil surface, feeding liverwort and moss where they live. An alternative nutrient-delivery system is to focus at least partly on incorporation of controlled-release fertilizers (CRF) in the soil medium, where the majority of nutrients are located safely away from the soil surface. Use CRF formulations that cover the duration of the seedling's life in the container, as top-dressing of CRF returns a grower to a situation where liverwort and moss are fed where they live, that is, on the soil surface. Recent research, however, indicates that iron sulfate in CRF form top-dressed on containers has a strong inhibitory effect on liverwort, with reduced concern over nutrient toxicity due to the slow release of the product (Prine 2010).

Post-Emergent Options, or Lack Thereof

All the best management practices in the world may not prevent moss and liverwort outbreaks, particularly when cloudy, cool weather seems to work against you. Hand-weeding is an option, but that can damage the crop through disturbance of shallow roots or soil loss. Due to the tendency of liverwort to fragment, it sometimes feels like weeding only spreads the problem.

Terracyte® (BioSafe Systems, East Hartford, CT) (sodium carbonate peroxy-hydrate) is a granular product labeled for post-emergent control of liverwort and moss. In the presence of water, the granules convert to 34% hydrogen peroxide, strong enough to burn any foliage it contacts. While the product may be applied safely on larger containers where foliar contact can be avoided, the granules tend to hang up in any sort of denser foliage. Dense foliage also tends to reduce the uniformity of application, which diminishes uniformity of liverwort and moss control.

Mogeton (Certis, Amesbury, Wiltshire, UK) or Gentry (Chemtura Corporation, Middlebury, CT) (quinoclamine) is a post-emergent originally used to reduce moss in rice paddies. Researchers have demonstrated excellent control over a range of species and stocktypes with considerable residual, but the parent company withdrew the product from a long EPA registration process in early 2008.

Essential Oils—An Alternative Means of Control

Essential oils are distilled plant extracts. Some essential oils have insecticidal, fungicidal, bactericidal, herbicidal properties, or all of the above. Modes of action are poorly understood, but ancient Egyptians used thyme oil (with the phenolic compound thymol) to preserve mummies from fungal and bacterial attack. For weeds such as liverwort and moss, essential oils are thought to simply act as a contact herbicide. Thorough coverage of the intended target is necessary for proper membrane disruption and weed death

to occur. A grower can take advantage of the limited or non-existent cuticle of liverwort and moss to burn these plants while waxier surfaces, such as conifer needles, are relatively protected.

Growers in the Pacific Northwest first experimented with Cinnamate (cinnamon oil) (Acros Organics, Fairlawn, NJ), a product labeled for two-spotted spider mite control that turned out to control liverwort and moss as well. Due to factory safety issues, Cinnamate is no longer produced. Sporatec™ (Brandt Consolidated, Springfield, IL; formerly sold as Sporan by EcoSMART Technologies Incorporated, Franklin, TN) is a product that consists of rosemary, clove, and thyme oil. The product is primarily labeled as a fungicide, but is now labeled for liverwort and moss as well. Sporatec™ is a FIFRA 25(b) product, meaning it is exempt from EPA registration. There is no re-entry interval and no pre-harvest interval. Even so, essential oils like Sporatec™ are concentrated oils and should be handled carefully. They can irritate skin, and are particularly troublesome to contact lens wearers. If you spray near harvest time, I strongly recommend that handlers wear gloves.

Trials With Essential Oils

The Stuff Actually Works!—During the past several years, we have tested a fair number of products with wide-ranging and astounding claims. Growers like to call these products snake oils, and Sporatec™ certainly struck us as distilled snake oil at first blush. Nonetheless, we first tested the product on a liverwort and moss-infested crop of western redcedar (*Thuja plicata*) seedlings grown in Styroblock™ 2A (313A) containers (40 cm³ [2.4 in³]) in the fall of 2008. We conducted a replicated test at 0, 8, 15.5, and 31 ml/l (0, 1, 2, and 4 oz/gal) rates and, with each rate, included 0.03% spreader-sticker (Sylgard® 309) and 0.45% Hasten® penetrant (Wilbur-Ellis, Fresno, CA) based on general label recommendations to include these types of adjuvants to improve efficacy. The label encouraged thorough coverage, and we applied at a rate of 2.3 l/m² (70 oz/10 ft²). While the 15.5 ml/l (2 oz/gal) rate showed some tip burning of the redcedar, from which it recovered, and the 31 ml/l (4 oz/gal) rate severely burned foliage, the 8 ml/l (1 oz/gal) rate showed no damage to the crop (Figure 2). Spraying 8 ml/l (1 oz/gal) not only did not damage the redcedar, but successfully controlled liverwort and, to a lesser extent, moss (Figures 3 and 4). We recorded 91% liverwort control and 75% moss control 9 days after treatment.

We followed this trial one week later with a second rate comparison over western redcedar, this time at 0, 4, 8, 12 ml/l (0, 0.5, 1.0 and 1.5 oz/gal) rates. We substituted Syl-tac® (Wilbur-Ellis, Fresno, CA), a combination of Sylgard® 309 and Hasten®, by keeping the Sylgard® rate the same, we decreased the rate of Hasten® penetrant in this combination product to one-quarter the rate of the first trial. Even though the same volumes of product were applied in fairly similar environmental conditions, control was not as thorough. Even the 12 ml/l (1.5 oz/gal) Sporatec™ rate in this second trial controlled only 81% and 62% liverwort and moss, respectively, 7 days after treatment (not shown). Since these were not head-to-head trials, we can only infer that the lower rate of penetrant led to the weaker control.

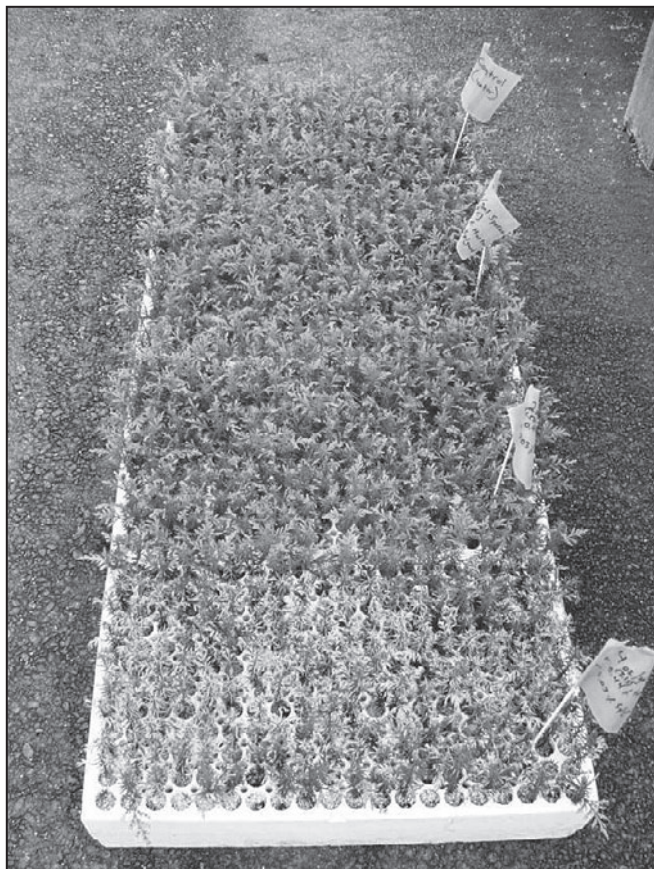


Figure 2. One replication of Sporatec™ applied (from top to bottom) at 0, 8, 15.5, and 31 ml/l (0, 1, 2, and 4 oz/gal) rates at a volume of 2.3 l/m² (70 oz/10 ft²). Photo is 9 days after treatment.



Figure 3. Comparison of healthy liverwort (untreated) with severely damaged liverwort treated at 8 ml/l (1 oz/gal).

Oregon State University Test—Ed Peachey, an extension agent from Oregon State University, tested over-the-crop Sporatec™ applications at a nursery in Independence, OR, in 2009. The nursery had 4-l (1-gal) pots of arborvitae (*Thuja occidentalis*) and Oregon grape (*Mahonia aquifolium*) coming out of dormancy in spring with thick liverwort infestations. Sporatec™ was applied at rates of 8 and 12 ml/l (1 and 1.5 oz/gal), with and without various adjuvant combinations, including the combination and rates from our first trial. Applications were made in succession on 20 April and 24 June 2009. He found greater than 85% liverwort control up to 9 weeks following application at both rates, with some minor phytotoxicity to Oregon grape foliage. There did not appear to be increased performance with addition of any adjuvant combination, but there was a trend of less phytotoxicity when adjuvants were included. Franki Wai-Ki Lam of Brandt, Incorporated believes the spreader may have decreased crop phytotoxicity by breaking down the surface tension of the oil droplets, thus lowering their tendency to burn broadleaf foliage.

Tests at Webster Nursery—In 2009, liverwort and moss growth was poor, but we did have some decent growth of liverwort and moss in some larger 4-l (1-gal) stock by fall. In early October 2009, we tested direct sprays on liverwort and moss beneath a range of species, including western hemlock (*Tsuga heterophylla*), Sitka spruce (*Picea sitchensis*), Douglas-fir (*Pseudotsuga menziesii*), western white pine (*Pinus monticola*), ponderosa pine (*Pinus ponderosa*), noble fir (*Abies procera*), grand fir (*A. grandis*), western redcedar, and Port-orford cedar (*Chamaecyparis lawsoniana*). We found no phytotoxicity when direct spraying rates as high as 15.5 ml/l (2 oz/gal) Sporatec™. While superficial spray coverage on conifer foliage did not result in any burn, needles tended to be quite waxy by this time of year. Roots were also suberizing by this time. Liverwort and moss were successfully knocked back, with 95% and 88% control, respectively, 3 weeks after treatment, and 93% and 76% control 6 weeks after treatment.

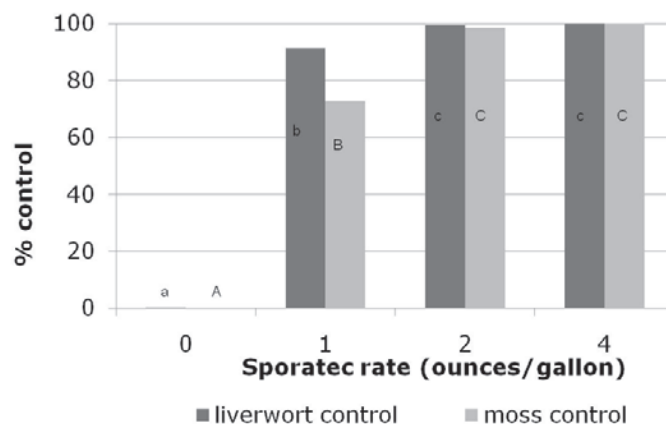


Figure 4. At 9 days after treatment for the 8 ml/l (1oz/gal) treatment, we recorded 91% liverwort control and 75% moss control. Crop phytotoxicity was observed at 15.5 ml/l (2 oz/gal) rates and above.

Irrigation Boom Trials—All trials to this point involved some sort of hand-held spray apparatus. The next step was to chemigate the product through an irrigation boom, allowing for improved speed and accuracy. We also wanted to further test over-the-crop spraying, particularly over early- to mid-season conifer “liners.” For these trials, we used a Dosatron® injector (Dosatron International, Clearwater, FL), set at the strongest rate of 1:50. We further diluted this baseline 2% setting by making a pre-mix concentrate of one part oil to several parts water (Figure 5). This allowed us to constantly agitate the pre-concentrate, ideally creating a more uniform downstream application by minimizing settling of the product in the irrigation line. We did not include any adjuvants.

After a disastrous first trial where we over-applied volume of product, several additional trials allowed us to refine rates and volumes to the point where we were getting up to 90% control of liverwort and 75% control of moss, with no phytotoxicity to sensitive species like western hemlock in the middle of its growing season. Unfortunately, these reduced rates only temporarily knocked back the weeds for 10 to 14 days, and further trials are needed to see whether repeat applications on a shorter timeline can better control liverwort and moss in midseason crops.



Figure 5. For the boom irrigation trials, we started with a Dosatron® injector setting of 1:50. We further diluted one part oil to several parts water, allowing us to pre-agitate the product for better downstream uniformity.

Fine tuning of rates meant that 50% over-application might mean crop damage, where 50% under-application would result in no control. To prove to ourselves that we were accurately applying product downstream, we collected boom samples both between trials and within a trial (near beginning and near end of trial) and sent these off for analysis at the British Columbia lab where the product was developed. Lab analysis showed that our system was accurate to within +/- 15%, which is important when applying an herbicide over plants.

Suggested Guidelines

Consider these a starting point for rates to test in your nursery. Always test a small sample first.

Over-The-Crop Sporatec™ Applications

Based on our trials, the following is a suggested guideline for over-the-crop Sporatec™ applications that are applied with the intention of killing only the liverwort and moss:

1. For early to mid-season applications, apply 4.7 ml/l water (0.6 oz/gal water; 0.47%) Sporatec™ with a volume of 4.9 l/m² (150 oz/10 ft²) or 5.8 ml/l (0.75 oz/gal; 0.59%) in a volume of 3.3 l/m² (100 oz/10 ft²).
2. For late-season over-the-crop sprays, apply 8 ml Sporatec™/l water (1.0 oz/gal water; 0.78%) in a volume of 3.3 to 4.9 l/m² (100 to 150 oz/10 ft²).
3. We noted a range of crop resistance, from toughest to most sensitive: ponderosa pine>true firs>interior Douglas-fir>coastal Douglas-fir> western redcedar> western hemlock>western larch (*Larix occidentalis*).
4. Use extreme caution when treating broadleaves. We noted at least some level of phytotoxicity on all broadleaves we tested, including red alder (*Alnus rubra*), black cottonwood (*Populus trichocarpa*), and creeping Oregon grape. If you do apply over the top of broadleaves, consider pre- and post-wetting the foliage.

Directed-Spray Sporatec™ Applications

Season-long at 8 ml Sporatec™/l water (1.0 oz/gal water). Where moss is present, consider using up to 1.2 ml/l (0.16 oz/gal) Syl-tac®, as this may improve control.

Late-season at 12 ml Sporatec™/l water (1.5 oz/gal water). Again, consider using 1.2 ml/l (0.16 oz/gal) Syl-tac® where moss is present. Do not apply this rate to containers less than 98 cm³ (6 in³) or to plants that have not hardened off.

Season-long at 12 ml Sporatec™/l water (1.5 oz/gal water) in the second season of a container crop.

One important note is to figure out the minimum volume of product you need for the stage of liverwort and moss in your crop and apply only that amount. It is relatively easy to over-apply when direct spraying. When going after a nasty infestation, remember that more volume equals more active ingredient!

Checklist for Success _____

When applying Sporatec™, consider the following checklist:

1. Soften water to hardness <100 ppm. The label says 200 ppm, but the original developer suggests 100 ppm is a more appropriate cutoff.
2. Adjust water pH to 7.0 or lower.
3. Try to apply when temperatures are greater than 16 °C (60 °F) and less than 29 °C (85 °F).
4. Remove contact lenses (preferably before application).
5. Maintain constant agitation throughout. Settling of oil will lead to uneven application rates.
6. A post-application water rinse 5 minutes after spraying may reduce phytotoxicity in sensitive species, particularly broadleaves.

Final Disclaimer _____

Many plants were harmed in the testing of this product! Always conduct small trials first; use extreme caution when testing with broadleaves, and remember that more is not always better!

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