CHAPTER 7-1
GARDENING: HORTICULTURAL USES

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Figure 1. *Sphagnum* species such as this *S. russowii* are commonly used in horticulture as bedding material. Photo by Michael Lüth.

Horticultural Uses

I was surprised that in my search for moss uses in horticulture I stumbled on a patent for culturing "moss seedlings" (Hiraoka 1995). The patent was to culture mosses that could henceforth be transplanted and grown in a nursery. Hiraoka presented this as a means of reducing the necessity of collecting wild mosses and creating undesirable forest conditions due to drying soils and erosion. This consideration should serve as a warning for all who desire to use bryophytes for any commercial purpose, and even on a small personal scale, collection can produce local damage.

"People have probably used organic materials as an aid for plant culture since the eve of human history, but documentation is scarce" (Raviv et al. 1986). Use of organic materials, including mosses, may not have started that early, but if monkeys can discover the advantage of mosses for getting water to drink, why not? At the beginning of the 18th Century, we find reference to using peat moss as an amendment for clay soils, whereas animal dung was used for sandy soils (Raviv et al. 1986). Since then, the need to keep plants alive during transfer made bryophytes a desirable medium because of their ability to retain moisture.

It is surprising how difficult it is today to find literature on the use of bryophytes in plant cultivation, despite the widespread sale of peat mosses for gardening, potting, air layering, and other uses. Rather, the use of mosses, especially peat moss, seems to be assumed and publications concentrate on finding substitutions for it (e.g. Tripepi et al. 1996) or creating the right mix of moss and amendments (e.g. Chong & Lumis 2000; Shujun et al. 2004).

Horticulture is the largest market for moss products in Asia (Tan 2003), and probably in most North American countries (Muir et al. 2006). In horticulture, mosses find a niche unparalleled in any other living bryophyte industry (Nelson & Carpenter 1965; Tan 2003). In some parts of
Bryophytes, especially peat mosses (Figure 1), have played a major role in horticulture for centuries (Perin 1962; Arzeni 1963; Adderley 1964, 1965). Although their use as part of the landscape in gardens has traditionally been mostly an Asian practice, they have commonly been used as soil additives and bedding for greenhouse crops, potted ornamental plants, and seedling beds (Cox & Westing 1963; Sjors 1980). They are stuffed into wire frames to make totem poles to support climbing plants (at the Mossers Lee Plant), topiary (Figure 2), moss-filled wreaths, or baskets (Thomason 1994), or for covering the soil in floral arrangements. One company advertises a birch bark pedestal topped by a moss globe.

Overuse of mosses is concerning in several countries. Thus, some horticulturists seek substitutes. The use of rice hulls may provide a more renewable alternative to Sphagnum (Figure 1) peat for horticulture usage (Sambo et al. 2008). Peat has more total pore space and a lower air-filled pore space compared to rice hulls, coinciding with a higher water-holding capacity and the highest water content at container capacity. Nevertheless, peat had a lower available water content than the rice hulls, while releasing its water more slowly.

**Shipping and Protecting**

*Sphagnum* (Figure 1) is almost indispensable for shipping live plants, keeping them moist, yet free from mold. In countries where peat is abundant, the damp peat is burned to produce a smoke screen against frost, hence protecting the plants (Thieret 1954). This is one of its uses in Asian countries as well (Tan 2003).

**Soil Conditioning**

The Shuswap Indians of North America use *Aulacomnium* (Figure 3) and *Dicranum* (Figure 4) mixed with dirt to make plants healthier (Palmer 1975). As a soil conditioner, coarse-textured mosses increase water storage capacity; fine-textured mosses provide air spaces (Ishikawa 1974; Bernier 1992; Bernier et al. 1995). Although supporting experiments seem to be lacking, we assume that mosses improve the nutrient condition of outdoor soils by holding nutrients, especially from dust and rainfall, then releasing them slowly over a much longer period than normal nutrient residency near the soil surface (Stewart 1977; Rieley et al. 1979; Seafone unpubl. data).
from the field site could make the peat inconsistent and alter the water-holding capacity and aeration needed for good plant growth. Therefore, they recommended that the proportion of subshrub residues not exceed 3% wet weight, that the proportion of cotton grass and sedge residues not exceed 6%, and that the proportion of \textit{Sphagnum} (Figure 1) residues be at least 90% (Puustjarvi 1982).

In remote places, including national parks, remote villages, and other places where sewage systems are not in place, peat may be mixed with human waste to form compost (Wikipedia 2017). The extra aeration provided by the spaces among the peat plants helps the process of breaking down the sewage. Nevertheless, human pathogens can be a problem, with the greatest of these being \textit{Ascaris} eggs (a nematode parasite; Figure 5-Figure 6) (Hill 2013). A long time or high temperatures are needed to destroy these pathogens. Berger (2011) claims that the compost should be free of live pathogens after at least two weeks at 55°C or one week at 60°C.

In England, the Wye College, University of London, and Southern Water have cooperated to develop a compost that takes advantage of sewage, mixed with peat mosses, providing a valuable soil conditioner and slow-release fertilizer that can be used for container-grown plants (Lopez-Real \textit{et al}. 1989).

One use for the nasty-smelling fish offal takes advantage of the absorptive properties of \textit{Sphagnum} (Figure 1) to create a superior compost (Martin & Chintalapati 1990), a real boon for getting rid of fish waste. And, when mixed with fish processing wastes, peat mosses are superior to sawdust and wood shavings in conserving nitrogen, but are a bit more expensive (Liao \textit{et al}. 1995).

Martin (1992) considered that it should be an easy and inexpensive process to use fish by-products (fish offal) with \textit{Sphagnum} (Figure 1) peat as a substrate to grow microorganisms for submerged fermentation. Martin conducted experiments on growing fungi and yeast as potential sources of microbial biomass protein for feeding animals. These products, which the fish were willing to include in their diet, served successfully as proteinaceous food for feeding farmed fish.

One of the microorganisms tested was the acid-tolerant fungus \textit{Scytalidium acidophilum} (Figure 7) (Martin & Chintalapati 1989). Martin and Chintalapati found that the culture did not produce any better concentration of the fungus dry weight than when they used a diluted \textit{Sphagnum} (Figure 1) peat hydrolysate as the substrate source. Martin and Chintalapati (1990) considered that the higher production of nutrients such as nitrogen in the fish offal mixed with peat made this a "promising" source of protein produced by \textit{Scytalidium acidophilum}.

Johnston \textit{et al}. (1992) similarly worked with people from the Wisconsin Sea Grant Inst to find a suitable use for fish by-products to provide a useful compost. They found that the wide range of values for the C:N ratios and other properties related mostly to the initial C:N ratio and the time the mix of peat and fish by-products had been allowed to cure. The \textit{Sphagnum} (Figure 1) peat fish by-product composts, especially those with higher C:N ratios, compared well with commercial fertilized mixes.
As with human waste, destruction of pathogens is important for the fish waste, but Liao and coworkers (Liao 1997; Liao et al. 1997) found that the rise in temperature during composting, plus the ammonia and volatile fatty acids produced, were sufficient to destroy the pathogens. Addition of fir (Abies) or alder (Alnus) chips (Figure 8) caused the compost to stabilize sooner.

The addition of Sphagnum fuscum (Figure 9) peat to hog manure reduced the volatile loss of ammonia, a primary source of nitrogen, by 75%, mainly due to lowered pH, making it a more suitable fertilizer (Al-Kanani et al. 1992a). It offers the added advantage of preventing release of offensive odors caused by 1,2-ethanodiamine, methyl hydrazine, N-methyl methanamine, 3-methyl 2-butanimine, ethanethioic acid, and methanethiol (Al-Kanani et al. 1992b).

Rao and Burns (1990) found yet another way of providing nitrogen in the culture of oil-seed rape. They provide Cyanobacteria (nitrogen fixers; Figure 10) and bryophytes in the growing medium. Bryophytes are well known for their ability to harbor Cyanobacteria.

Miller (1981) found that bryophytes can even increase the buffering capacity of the soil, surprisingly even against the abrupt changes resulting from fertilizer. And as a mulch, the slow decomposition of peat mosses makes them much more long-lasting than leaf litter and compost.

Some mosses, for example the epiphytic Octoblepharum albidum (Figure 11), are especially suitable for growing hard-to-grow epiphytic ferns (Arzeni 1963). In the Philippines, Leucopanthes octoblepharioides (see Figure 12) and other members of the family are used by gardeners and plant growers instead of peat moss in potting new plants (Ben C. Tan, pers. comm.). Leucobryum (Figure 13) is a suitable medium for inducing good root sprouts on orchid cuttings, sold at U.S. $0.50 per kilo (in 1963), increased to US $1 in 1986 (Tan 2003). The most popular moss medium for growing orchids, most of which are likewise epiphytes, is Sphagnum (Figure 1), but mosses like Homalothecium arenarium (Figure 14), Hypnum imponens (Figure 15-Figure 16), Leucobryum spp. (Figure 13), Rhytidiopsis robusta (Figure 17), and Thuidium delicatum (Figure 18) are also useful (Perin 1962; Adderley 1964, 1965). Chen and Chang (2000a, b) had almost 100% survival success when growing the orchid Oncidium (Figure 19) from callus explants on Sphagnum peat. Whereas most of their culture media produced abnormal shoots, both embryo-and shoot-bud-derived regenerants developed into healthy plantlets when potted in Sphagnum and acclimatized in the greenhouse.
Figure 12. *Leucophanes* sp. *Leucophanes octoblepharioides* is used instead of peat moss in the Philippines for planting new plants. Photo by Niels Klazenga, with permission.

Figure 13. This epiphytic species of *Leucobryum* demonstrates its suitability for supporting root growth by hosting an epiphytic fern. Photo by Janice Glime.

Figure 14. *Homalothecium aureum* may be used as a substitute for peat in potting young plants. Photo by Jan-Peter Frahm, with permission.

Figure 15. *Hypnum imponens* growing in a sheet on a log. Photo by Janice Glime.

Figure 16. *Hypnum imponens*, a moss that may be used as a substitute for peat in potting young plants. Photo by Janice Glime.

Figure 17. *Rhytiopsis robusta*, a moss that may be used as a substitute for peat in potting young plants. Photo by Blanka Shaw, with permission.
Figure 18. *Thuidium delicatulum*, a moss that may be used as a substitute for peat in potting young plants. Photo by Janice Glime.

Figure 19. New *Oncidium* hybrid pseudobulb that must form a mycorrhizal connection. Photo by Consuelo Tugnoli, through Creative Commons.

But one consideration is that orchids are mycorrhizal (see Figure 20). That means they require an appropriate fungal partner in order to successfully form plants from seeds or cuttings. Kreier (2003) reasoned that a fungus that was mycorrhizal to bryophytes might be a good place to find a proper associate for the orchids. Several members of the liverwort family *Aneuraceae* (Figure 21) are mycorrhizal in association with the fungal genus *Tulasnella* (Figure 21-Figure 22). Kreier reasoned that if the orchids have the same mycorrhizal fungi, then it should be possible to use those liverwort associations to inoculate the orchids with mycorrhizae from the liverworts. Oberwinkler *et al.* (2017) reported *Tulasnella* species are worldwide and likewise are associated with orchids on a global scale. The possibilities look good.
Air Layering

Horticulturists may have learned some lessons from nature. Mosses in nature provide suitable media for air layering of plants like the heath shrub Calluna (Figure 23) (Scandrett & Gimingham 1991; MacDonald et al. 1995) and even some tropical trees. MacDonald and coworkers (1995) demonstrated that layering was actually associated with the absence or low abundance of the mosses *Hypnum cupressiforme* (Figure 24) and *H. jutlandicum* (Figure 25) and *Cladonia* lichens (e.g. Figure 26). On the other hand, there seems to be a weak connection with layering in *Sphagnum* spp. (Figure 1), *Leucobryum glaucum* (Figure 27), and pleurocarpous mosses other than *Hypnum*.

Figure 23. *Calluna vulgaris*, a species that undergoes air layering in mosses in nature. Photo by Willow, through Creative Commons.

Figure 24. *Hypnum cupressiforme*, a moss that is negatively associated with air layering of *Calluna* in nature. Photo by Michael Lüth, with permission.

Figure 25. *Hypnum jutlandicum*, a moss that is negatively associated with air layering of *Calluna* in nature. Photo by Janice Glime.

Figure 26. *Cladonia fimbriata*, a moss that is negatively associated with air layering of *Calluna* in nature. Photo by Paul Cannon, through Creative Commons.

Figure 27. *Leucobryum glaucum*, a moss that can contribute to air layering of *Calluna*. Photo by Janice Glime.
Despite these somewhat weak connections for *Calluna* (Figure 23), mosses, especially *Sphagnum* (Figure 1), are used almost exclusively for air layering as a means of propagation of plants. The moss is wrapped (Figure 28) around the area where roots (Figure 29) are to be encouraged, often held in place with cloth mesh, wire, or dark plastic (Figure 30). The moss provides a continuous supply of moisture and encourages the development of adventitious roots while discouraging fungi. Once the roots have formed, the stem can be cut below that point and the explant grown into a new individual (Figure 31). Pant (1989) reports similar use for grafting fruit trees.
In addition to its ability to promote root sprouts in orchid cuttings, *Sphagnum* (Figure 1) is suitable for air layering of a number of kinds of plants, including trees for bonsai (Tan 2003). The moisture and antimicrobial properties are beneficial in the development of new shoots and roots.

It appears that preparing a tree for bonsai often involves air layering with mosses (Morrow 2001; Hasegawa 2002; Relf 2009). In their book on bonsai, Yoshimura and Halford (1957) provide instructions for making a bonsai. Mosses, usually *Sphagnum* (Figure 1), are wrapped around the stem, including a location with young buds, and covered with a material like plastic to retain the moisture. If the plastic is transparent, you can see when the new roots and branches have formed. The lower part of the old stem is then cut off and the layering removed. The bonsai is ready for planting.

**Pot Culture**

Mosses can also encourage growth of potted plants. Pant (1989) reports that *Begonia* (Figure 32) and *Fuchsia* (Figure 33) bud and flower more profusely in pots where mosses are used to separate the humus-rich top soil from the bottom soil. Members of the Ericaceae, in particular, benefit from the acid of peat mosses. But in Japan, *Hypnum plumaeforme* (Figure 34), *Leucobryum bowringii* (Figure 35), *L. neilgherrense*, and occasionally *L. scabrum* (Figure 36) fragments are used, mixed with sand or soil, to cultivate *Rhododendron* (Figure 37) shrubs (Ando 1957). Could it be that these mosses also acidify the soil?

Figure 32. Potted begonias, a genus whose growth is encouraged by potting with mosses in the mix. Photo by Pixabay, through Creative Commons.

Figure 33. Potted Fuchsias, a genus whose growth is encouraged by potting with mosses in the mix. Photo by pxhere, through Creative Commons.

Figure 34. *Hypnum plumaeforme*, a species used in Japan with sand or soil to cultivate *Rhododendron* shrubs. Photo by Janice Glime.

Figure 35. *Leucobryum bowringii*, a species used in Japan with sand or soil to cultivate *Rhododendron* shrubs. Photo through Creative Commons.
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Figure 36. *Leucobryum scabrum*, a species used in Japan with sand or soil to cultivate *Rhododendron* shrubs. Photo Taiwan Encyclopedia of Life, through Creative Commons.

Figure 37. *Rhododendron*, a genus that benefits from having mosses in the potting mix. Photo by Pete Bobb, through Creative Commons.

The forestry industry likewise finds peat invaluable for culturing young seedlings (see also Reforestation below). Heiskanen and Rikala (2000) found *Sphagnum* (Figure 1) peat to be superior to fine sand or peat with perlite, the latter resulting in more weakened seedlings as a consequence of the lower water retention of the medium. However, peat is not always readily available. Israeli researchers found that composted cattle manure mixed with grape marc were good substitutes for peat in that country where peat must be imported; the substitutes were likewise effective at suppressing plant pathogens (Chen *et al.* 1992).

In other cases, the pots themselves (Figure 38) are made of mosses. These are good for starting seedlings and can be planted without removing the plants. Roots will eventually penetrate the pot and grow into the soil.

Figure 38. 3-Inch Jiffy pot of peat moss fibers from Second Sun Garden Supply. Photo from Second Sun Garden Supply, modified by Janice Glime.

**Potting Medium**

In parts of Asia, horticultural mosses include *Vesicularia* (Figure 39), *Bazzania* (Figure 40), *Heteroscyphus* (Figure 41), and *Pallavicinia* (Figure 42) (Tan 2003). Orchid growers in particular use *Leucobryum* (Figure 35-Figure 36, Figure 43) and *Sphagnum* (Figure 1, Figure 44), especially for their ability to store large amounts of water in their **hyaline cells** (Figure 43-Figure 44).

Figure 39. *Vesicularia vesicularis* var. *vesicularis*. The genus *Vesicularia* is among the horticultural mosses in Japan. Photo by Michael Lüth, with permission.
Bazzania trilobata, a leafy liverwort. The genus Bazzania is among the horticultural bryophytes used in Japan. Photo by Ondřej Zicha (Discover Life), through Creative Commons.

Heteroscyphus fissistipus, a leafy liverwort. The genus Heteroscyphus is among the horticultural bryophytes used in Japan. Photo by David Francis, through Creative Commons.

Pallavicinia lyellii, a thallose liverwort. The genus Pallavicinia is among the horticultural bryophytes used in Japan. Photo by Des Callaghan, with permission.

Leucobryum glaucum leaf cells showing alternating hyaline and photosynthetic cells. Photo by Ralf Wagner <www.drralf-waner.de>, with permission.

Sphagnum palustre photosynthetic (green) and hyaline cells. Note that the hyaline cells are not short cells, but are elongate cells with bars across them. Photo by Malcolm Storey through Creative Commons.

Sphagnum (Figure 1) and Leucobryum (Figure 35-Figure 36) seem to be particularly preferred as a potting medium for orchids (Tan 2003). Tan reported the use of Leucobryum as a substitute for peat moss to grow orchid cuttings in Asia. The mosses, especially Sphagnum, were good as a potting medium for a variety of seeds.

But in North America, diversity of mosses as a potting medium seems to be absent. I searched with Google for "potting medium moss" and stopped after the 20th hit. All 20 of the mosses were named as peat moss or Sphagnum (Figure 1).

Dangers of Peat Culturing

There are drawbacks to using mosses in culturing of some plants. We have seen that Sphagnum (Figure 1) can be dangerous because of its cohabiting fungus that causes sporotrichosis (Chapter 1 of this volume). In containers of conifer seedlings, they can choke young seedlings, compete for nutrients, and repel water (Haglund et al. 1981). But they can also pose serious dangers. But causing fires? As Michael Richardson shared with Bryonet on 20 June 2013,
peat, including shrubs and other debris along with the mosses, is good potting material, but it can be flammable under the wrong circumstances. The oxygen available in the pot can permit decay to occur, causing heat that is amplified if the pot is in the sun. An article in the *Northumberland News* reported a house fire in June 2013 that was attributed to a pot with peat mosses on a second floor balcony. The deputy chief of the fire department said that the dry peat can easily ignite and can, after being in direct sunlight long enough, ignite by itself. This was not his first experience with flower beds on fire. His advice is to use non-combustible flower pots (not plastic), such as concrete or metal.

**Covering Pot Soil**

Sheet mosses are frequently used to cover the soil in pots housing flowering plants (Nelson & Carpenter 1965). This is especially true when they are sold by florists. Species of *Leucobryum* (not a sheet moss; Figure 35-Figure 36) can be used for this purpose, providing a pale green color contrast to the green of most tracheophyte leaves. In some cases, the strong anti-microbial properties of bryophytes might reduce invasions of bacteria and fungi.

Mat-forming mosses are typically sold as sheet mosses (Figure 45) (Peck *et al.* 2001). These are pleurocarpous mosses that grow horizontally, often on logs. Collectors strip the logs, and sometimes low branches, of their mats. In the eastern USA, one of the mosses used is *Thuidium* (Figure 46).

![Sheet Moss](image)

Figure 45. A package of sheet moss being sold in a gardening shop in Ohio, USA. Photo by Janice Glime.

![Thuidium](image)

Figure 46. *Thuidium* sheet moss, sold at a gardening shop in Ohio, USA. Photo by Janice Glime.

**Culturing Mushrooms and Other Fungi**

*Sphagnum* (Figure 1) peat is the substrate of choice as casing medium for cultivating the common grocery store mushroom, *Agaricus bisporus* (Figure 47) (Eicker & van Greuning 1989; Reddy & Patrick 1990; Jarial *et al.* 2005). (Casing is the process in which a non-nutritious layer, in this case peat, is applied over the colonized substrate so that the mycelium has access to more moisture, thereby increasing the size and number of growths.) Sungrow had a multi-million-dollar contract from Campbell (of Campbell soup fame) to improve mushroom culturing using a *Sphagnum* mix (Vitt, pers. comm.; Miller 1981). However, in places such as South Africa, where there is no peat, substitutes are necessary. The need for peat substitutes led Eicker and van Greuning (1989) to test other substrata and compare, but peat still gave the highest yields compared to eight other materials, with only weathered, spent compost offering similar results. Other types of mushrooms are grown in peat as well, such as *Pleurotus ostreatus* (Figure 48) (Manu-Tawiah & Martin 1986).

![Agaricus bisporus](image)

Figure 47. *Agaricus bisporus*, a species commonly grown in *Sphagnum*. Photo by I. G. Safonov, through Creative Commons.

![Pleurotus ostreatus](image)

Figure 48. *Pleurotus ostreatus* on a mossy tree trunk. This species can be cultivated in peat. Photo from Charl de Mille-Isles.
In an attempt to make further improvements in mushroom success, Beyer (1997) sought ways to reduce the effect of accumulated substances on late mushroom crops. Surprisingly, he found that the addition of Hypnum (Figure 15-Figure 16, Figure 24-Figure 25) peat to the compost improved later break yield, but the addition of Sphagnum (Figure 1) did not. One of the concerns is that the peat becomes infested with nematodes (Figure 49) and may carry Pseudomonas tolaasii (see Figure 50), the cause of bacterial blotch, both of which cause serious diseases to the mushrooms (Nikandrow et al. 1982).

Figure 49. Soil nematode, a common pest in Sphagnum that may carry the bacterium Pseudomonas tolaasii. Photo by Christina Menta, through Creative Commons.

Martin and Bailey (1983) succeeded in using peat as a fermentation medium in which acclimated fungi could be grown. They were more successful with the common mushroom Agaricus campestris (Figure 51) than with the morel Morchella esculenta (Figure 52) (Martin 1982). Martin and Bailey considered that growth inhibitors might be present in peat. Using sulfuric acid hydrolysates with autoclaved peat released a liquid that, when supplemented with nutrients, would enhance growth and crude protein content of these two edible fungi. Nutrient-supplemented peat hydrolysates enhance growth and crude protein content of fungal biomass.

Figure 51. Agaricus campestris, a species that grows well in a peat fermentation medium. Photo by Andreas Kunze, through Creative Commons.

A mixture of Sphagnum (Figure 1) with fish offal promises to be a suitable substrate for culturing the acid-tolerant fungus Scytalidium acidophilum (see Figure 7), which is considered to be a promising source of microbial protein (Martin & Chintalapati 1990). However, not all fungal cultures seem to benefit from peat mixtures. In one commercial operation, the yield of mushrooms improved when the peat was omitted from the cultivation medium (Smith 1983).

Figure 52. Morchella esculenta, the common morel, can be cultured in a bed of peat. Photo by Janice Glime.

Reforestation

The genus Tulasnella (Figure 21-Figure 22) is a mycorrhizal partner with several members of the thallose liverwort family Aneuraceae (Figure 21). If this fungus is likewise a partner with trees, then it should be possible to use those liverworts to help the trees to become established (Kreier 2003). In fact, Cryptothallus (Figure 21), a member of the Aneuraceae, shares its fungal partner with at least some members of the birch (Betula; Figure 53) and pine (Pinus; Figure 54) genera. Kreier found that both liverworts Riccardia palmata (Figure 55) and R. latifrons (Figure 56) grew on rotten wood and were well infected by
mycorrhizal fungi. Kreier also figured it would be relatively easy to disperse these liverworts on the forest floor, and that they would spread easily, preparing the soil with mycorrhizae that could partner with the trees. At that time, the fungi had been grown in culture but not the field. However, the discovery of rhizoidal bridges in tropical *Aneura* (*Aneuraceae*; Figure 57) provided a hopeful twist. In 2017, Oberwinkler *et al.* noted that *Tulasnella* species are worldwide in distribution and that they may occur in many forest ecosystems in association with wood. And we have already noted that they form mycorrhizal associations with orchids.

Figure 53. *Betula pendula*. Some members of the genus *Betula* share their fungal partner with the thallose liverwort *Cryptothallus*. Photo by Percita, through Creative Commons.

Figure 54. *Pinus strobus*. Some members of the genus *Pinus* share their fungal partner with the thallose liverwort *Cryptothallus*. Photo through Creative Commons.

Figure 55. *Riccardia palmata*, a species that grows on rotten wood and is infected by mycorrhizal fungi. Photo by Bernd Haynold, through Creative Commons.

Figure 56. *Riccardia latifrons*, a species that grows on rotten wood and is infected by mycorrhizal fungi. Photo by Bernd Haynold, through Creative Commons.

Figure 57. *Aneura pinguis*, a species that might be associated with *Tulasnella* on wood. Photo by Li Zhang, with permission.
Container Gardens

Mosses are commonly used in container gardens with **bonsai** (dwarfed ornamental tree; Figure 58) and **bonkei** (tray landscape; Figure 59), where they help to stabilize the soil and retain moisture for the shallow roots.

![Figure 58. Bonsai at Dawes Arboretum, Ohio, USA, showing dwarfed tree and mosses at base. Photo by Janice Glime.](image)

Selaginella, a relative of club mosses and not a true moss, is used to represent a tree, with mosses growing on the rocks that form the basin for a small "lake." Photo by Janice Glime.

Designers select the species of mosses to serve particular functions in the container landscapes. Large, upright mosses such as **Atrichum** (Figure 60), **Climacium** (Figure 61), **Dicranum** (Figure 4), **Polytrichum** (Figure 62), and **Rhodobryum** (Figure 63) simulate forests. **Bryum argenteum** (Figure 64) has a silvery, compact look that can simulate grasslands, and **Leucobryum** (Figure 27) usually has the role of a mountain. For snow-capped mountains, **Racomitrium canescens** (Figure 65) provides a frosted look. **Physcomitrium** (Figure 66-Figure 67), often a volunteer in greenhouse flower pots, is so miniature as to appear like a moss, or maybe a grass, in a landscape of **Leucobryum** mountains. **Barbula unguiculata** (Figure 68), **Funaria hygrometrica** (Figure 69), and **Weissia controversa** (Figure 70) can contribute to needs of intermediate size. In Mexico, some mosses are even used for fake bonsai: **Campylopus** (Figure 71), **Dendropogonella rufescens**, **Hypnum** (Figure 15-Figure 16, Figure 24-Figure 25, Figure 34), and **Thuidium** (Figure 18) (C. Delgadillo, pers. comm.). In the Pacific Northwest of North America, **Leptobryum pyriforme** (Figure 72), known as Kyoto moss, is sold for bonsai trays (J. Christy, pers. comm.). I would expect **Climacium** and **Polytrichum** to serve well as trees in miniature landscapes as well.

![Figure 60. Atrichum angustatum, in a genus used to simulate forests in tray gardens. Photo by Keith Bowman, with permission.](image)

![Figure 61. Climacium dendroides, simulating trees in a dish garden. Photo by Keith Bowman, with permission.](image)
Figure 62. *Polytrichum juniperinum*, in a genus used to simulate forests in tray gardens. Photo by Janice Glime.

Figure 63. *Rhodobryum roseum*, in a genus used to simulate forests in tray gardens. Photo by Michael Lüth, with permission.

Figure 64. *Bryum argenteum*, a species used to simulate grasslands or mountains in tray gardens. Photo by Tushar Wankhede, with permission.

Figure 65. *Racomitrium canescens*, a moss that is used to simulate snow on mountains. Photo by Michael Lüth, with permission.

Figure 66. *Physcomitrium pyriforme* in a dish garden. Photo by Michael Lüth, with permission.

Figure 67. *Physcomitrium pyriforme* with capsules, a common volunteer in flower pots. Photo by Janice Glime.
Figure 68. *Barbula unguiculata*, a moss of intermediate size to fill in as grass or other intermediate needs. Photo by Michael Lüth, with permission.

Figure 69. *Funaria hygrometrica*, a moss of intermediate size to fill in as grass or other intermediate needs. Photo by Michael Lüth, with permission.

Figure 70. *Weissia controversa*, a moss of intermediate size to fill in as grass or other intermediate needs. Photo by Michael Lüth, with permission.

Figure 71. *Campylopus introflexus*; the genus *Campylopus* is used in Mexico for fake bonsai. Photo by Michael Lüth, with permission.

Figure 72. *Leptobryum pyriforme*, a species that is used in the Pacific Northwest, USA, in bonsai trays. Photo by Michael Lüth, with permission.

**Bonkei**

Miniature tray landscapes [bonkei or *saikei* (art of creating tray landscapes that combine miniature living trees with soil, rocks, water, and related vegetation); Figure 73-Figure 76] in Japan use mosses to provide appropriate texture and color with little danger of damage due to drying (Kawamoto 1980; Oishi 1981). Such trays can delight the bed-ridden. Gerritsen (1928) arranged sixteen species of mosses in various stages of maturity to provide a changing landscape for a hospitalized friend: "Each day the mosses had changed appearance; so each day added a new joy. The nurses came from time to time to see and admire. Other patients shared its freshness and beauty. Visitors, too were invited to see the charm of a 'platter of mosses.'"

Figure 73. Bonkei with its miniature landscape containing mosses to simulate mountains. Photo courtesy of Hironori Deguchi.

Figure 74. Bonkei with mosses simulating trees with a rocky crag. Photo courtesy of Hironori Deguchi.
Dish Gardens

Dish gardens (Figure 78) are a scaled down version of bonkei. The size may not be scaled down, but they typically do not represent a landscape and may have only one bryophyte species (Figure 78), sometimes as ground cover for flowering plants like spring bulbs (Figure 79).

For making these miniature landscapes, Schenk (1997) recommends the usual potting mix of humus, including peat moss, ground-up tree bark, or rotted sawdust. He cautions that sand, vermiculite, or perlite can be used, but that they must be kept moist because they tend to have larger spaces and dry quickly near the surface, leaving the moss with no source of moisture.

Even in this seemingly harmless occupation, one must use caution against allergens. Tray gardens and other forms of bonsai and dish gardens may use *Sphagnum* (Figure 1) peat as a medium or even as the plants of interest (Figure 77). This moss is well known for its ability to harbor the fungus that causes sporotrichosis (Dong *et al.* 1995).

Figure 75. Bonkei simulating a volcano and surrounding mountains and forests. Photo courtesy of Hironori Deguchi.

Figure 76. *Selaginella* (a club moss relative) and moss bonsai, Kyushu, Japan. Photo by Janice Glime.

Figure 77. *Sphagnum* moss pot in Japan, a potential source of allergens. Photo courtesy of Hironori Deguchi.

Figure 78. Dish garden of moss. Photo courtesy of J. Paul Moore.

Figure 79. Dish garden for spring bulbs in cafe in Helsingborg, Sweden. Photo courtesy of Irene Bisang.

Figure 78. Dish garden of moss. Photo courtesy of J. Paul Moore.
Annie Martin, a prize-winning gardener and landscaper (Figure 81), runs classes for both adults and children in which she teaches them how to make dish gardens and terraria (Figure 82-Figure 83).

Similar to the dish gardens, moss rocks (Figure 84-Figure 85) have become popular in some places. These typically have a species of moss growing in a depression or on the surface of a rock.
Figure 84. *Dicranodontium denudatum* stone pots in shop in Hakone, Japan. These are a variation on the dish garden, but the mosses are grown on the surface or in a depression of a natural rock and typically have only one moss species. Photo courtesy of Hironori Deguchi.

Figure 85. Moss-Rocks-logo at Moss and Stone Gardens, Pennsylvania, USA, showing a more formal American version. Photo with permission from David Smith.

**Bonsai**

The term *bonsai* (Figure 86) refers to a dwarfed ornamental tree or shrub grown in a pot and prevented from reaching its normal size. Inoue (1972) pointed out that moss bonsai and moss bonkei (tray landscapes) are popular in Japan by both amateurs and professional horticulturists. But even bonsai trees are potted in wide pots and the soil is typically covered with mosses (Figure 86-Figure 89).

Figure 86. Bonsai at Dawes Arboretum, Ohio, USA, showing the dwarfed tree and mosses at its base. Photo by Janice Glime.

Figure 87. This bonsai arrangement incorporates features of bonkei with rocks and mosses giving it the look of a miniature forest. Photo by Janice Glime.

Figure 88. Bonsai at Dawes Arboretum, Ohio, USA. This bonsai uses a deciduous tree, and bryophytes can warn its owner to water it before the leaves begin to drop or become crispy. Photo by Janice Glime.

Figure 89. Bonsai using the fern *Osmunda lancea*. Courtesy of Hironori Deguchi.
The mosses can contribute to the success of the bonsai. When the mosses appear dry, you can be sure your bonsai needs water (Figure 90-Figure 91). However, mosses are not always the friends of the bonsai. The continuous moisture of the mosses can inhibit root growth and promote sudden fungal attacks. The experts advise removing the mosses each autumn to reduce fungal damage (Bland 1971).

Figure 90. Bonsai in Dawes Arboretum, Ohio, USA. Mosses on the roots are a good indicator when the soil is becoming dry and the tree needs water. Photo by Janice Glime.

Figure 91. Bonsai on wood, increasing the need for bryophytes to maintain root moisture and warn when it is time to water it. Photo courtesy of Annie Martin, MountainMoss.

In India, bonsai is included in horticultural texts. Dhanda (1984) suggests that the bonsai may be finished off with a layer of moss on top (Figure 92). Yoshimura and Halford (1957) likewise consider the mosses growing around the bonsai to be important. The mosses provide several advantages. They add aesthetic appeal, creating a more natural looking landscape. And they make watering easier, permitting a raised base on the tree while catching the water and protecting the furniture.

In Malaysia, bonsai makers typically use the acrocarpous mosses *Bryum* (Figure 93) and *Philonotis* (Figure 94), and sometimes the pleurocarpous mosses *Isopterygium/Pseudotaxiphyllum* (Figure 95) and *Vesicaria* (Figure 39) and the thallose liverwort *Riccia* (Figure 96) (Tan 2003). In Singapore, the moss *Ochrobryum kurzianum* is imported from Thailand for ornamental use in bonsai arrangements. In Japan, *Leucobryum* (Figure 27) is common in bonsai landscape design.

Figure 92. Bonsai at Dawes Arboretum, Ohio, USA, illustrating mosses covering the pot and signalling when the tree roots need more water. Photo by Janice Glime.

Figure 93. *Bryum capillare* with capsules, in a genus used in bonsai in Malaysia. Photo by Michael Lüth with permission.

In Malaysia, bonsai makers typically use the acrocarpous mosses *Bryum* (Figure 93) and *Philonotis* (Figure 94), and sometimes the pleurocarpous mosses *Isopterygium/Pseudotaxiphyllum* (Figure 95) and *Vesicaria* (Figure 39) and the thallose liverwort *Riccia* (Figure 96) (Tan 2003). In Singapore, the moss *Ochrobryum kurzianum* is imported from Thailand for ornamental use in bonsai arrangements. In Japan, *Leucobryum* (Figure 27) is common in bonsai landscape design.
Hanging Baskets

Mosses are often used in the construction of hanging baskets for flowers (Smith 1996). In California, USA, meter-long "strips" 8-10 cm wide are used to make hundreds of baskets per week!

In Asia, species of *Sphagnum* (Figure 1) are used to line hanging baskets (Tan 2003). Its ability to hold water and its antimicrobial activity make this a good substrate for the roots of flowering plants.

A wire frame is used to give the basket support, with mosses wound among the wires or laid within to provide the structure. Not only do they make an attractive, natural-looking basket, but they reduce the need for frequent watering (Lohr & Pearson-Mims 2001). Species of *Hypnum* (Figure 15-Figure 16, Figure 24-Figure 25, Figure 34) and *Sphagnum* (Figure 1) are commonly used for this purpose.

The long, stiff stems of *Polytrichum* (Figure 62) permitted the early Romans to weave it into baskets (Bland 1971), but these most likely did not have a horticultural purpose.

Terraria

The *terrarium*, a drier plant version of the aquarium, is often arranged like an enclosed garden (Figure 97), a miniature garden like the container gardens. Because of its small size, bryophytes are often used to give the look of mountains (Figure 98); dry brooks made of pebbles ramble between clumps of various hues of green. But bryophytes are not easy to grow in such conditions. If the container is fully open (Figure 98, Figure 99), mosses soon dry out and become crispy. If it is sealed (Figure 97, Figure 100-Figure 103), as many terraria are, fungi can easily grow. The best choice is to leave the top partially open to permit air circulation.
Figure 98. Open terrarium from MountainMoss. Note the mound of *Leucobryum* which is sometimes used to simulate mountains. Photo courtesy of Annie Martin.

Figure 99. Open terrarium with moss. Photo courtesy of J. Paul Moore, with permission.

Figure 100. In some covered terraria, small holes with plugs, similar to the green ones seen here, can be opened and even kept open to maintain at least some air movement and reduce condensation. Photo courtesy of Annie Martin of MountainMoss.

Figure 101. Tiered terrarium from MountainMoss. Photo courtesy of Annie Martin.

Figure 102. Terrarium with lid. Note the tiny figure that turns the tall mosses into "trees." Photo by Erin, through Creative Commons.
It seems appropriate to cite the first terrarium, known as the **Wardian case** (Figure 104), invented by Nathaniel Bagshaw Ward (1791-1868) (Hershey 1996). He had fallen in love with plants on a trip to Jamaica and despite ultimately pursuing a profession as a physician, he pursued plants through his attempts at gardening. But, sadly, his attempts at a moss and fern garden failed, due severe air pollution in the outskirts of London. It was this failure that led him to invent the Wardian case, or terrarium. He had placed a "chrysalis" (actually a moth pupa) in a bottle and observed it daily. Then, to his surprise, a "seedling" fern and a grass appeared. He considered the conditions and noted the need for "a moist atmosphere free from soot or other extraneous particles; light; heat; moisture; periods of rest; and change of air." He moved the bottle to the outside of a northern window and there the plants thrived for four years with no additional attention!

**Choice of mosses depends in part on how moist you intend to keep it and in part on the effect you want to achieve.** Polytrichum (Figure 62) can survive in a somewhat dry terrarium but will easily be covered with mold when it is too damp. Likewise, *Leucobryum* (Figure 27) likes it airy with good circulation. *Ceratodon purpureus* (Figure 105) is sometimes successful, again requiring at least some air circulation. Schenk (1997) states, "I must tell the whole truth by identifying the great enemy of terrarium gardening with native woodlanders, for there is one: mold." He admonishes that most terraria have a short life due to this problem. My own experience certainly agrees.

*Funaria hygrometrica* (Figure 69) can be encouraged in more moist conditions, but it still needs circulation. With a little luck it will even produce capsules. We successfully maintained *F. hygrometrica* in an uncovered aquarium in our university greenhouse. These lasted for several years, but we avoided getting tap water on them and only used misting from distilled water or tap water that had been allowed to sit to allow the chlorine to escape.
Schenk (1997) suggests that a container the size of an aquarium (Figure 106) is best, smaller ones being more subject to mold. Air space is of the essence, and it needs to circulate. He considers a potting mix to be suitable, whereas it does not tend to work well in open-air gardens. On the other hand, if the bryophytes have their own deep brown portions (Figure 107), no substrate is necessary. Charcoal may be added to the substrate to absorb excessive acidity and gases produced by decay. Little water is needed as it will recycle (Figure 108) within the nearly sealed container. Adding flowering plants can add color (Figure 109). Mosses that are collected wet generally do not need additional water and may even need to be dried by leaving the terrarium open wide for a day or two. Slightly dry mosses can be moistened with 30-35 ml (2-3 tablespoons) of water; totally dry ones may require up to 70 ml (1/4 cup) (Schenk 1997).

Figure 106. Kitchen terrarium in an aquarium. Photo by Janice Glime.

Figure 107. Campylopus flexuosus with brown base, needing no substrate. Photo by Michael Lüth, with permission.

Figure 108. Condensation on wall of kitchen terrarium, endangering a mold outbreak. Photo by Janice Glime.

Figure 109. Mix of a variety of plants with color (red-leafed Begonias, pale Tillandsias) and rocks in kitchen terrarium built in an aquarium. Photo by Janice Glime.

Maintenance for the first few days after planting is essential to avoid an immediate mold attack. Schenk (1997) advises that if a heavy dew (Figure 108, Figure 110) appears on the walls of the container, open it and dry the walls. This should be repeated daily until morning brings only a light condensation on the upper half of the walls of the container. When you discover, probably in a few weeks, that there is no longer any morning dew, it is time to add water, but not much.

Figure 110. Terrarium with moss, showing severe condensation that must be removed by drying the walls or keeping the container open until it is gone. Photo by J. Paul Moore, with permission.

After all this care, Schenk (1997) warns that the terrarium will most likely last only three weeks! (I have had better success than that with larger aquaria.) That can be extended by providing fluorescent lights to avoid the etiolated growth so noticeable in low light. Nevertheless, a mold garden is most likely to ensue within this short time,
and great care and luck are needed to find the right wetting and drying cycle.

Within those first few weeks, a moss garden terrarium can be full of surprises, with mushrooms appearing, capsules extending, and the somewhat rapid but unnatural elongation of the moss stems in low light.

One of the contributors to the demise of the moss terrarium indoors is the warm temperatures night and day indoors. If there is a cool location for the terrarium, it might survive a longer display, and surely in the refrigerator it would last, but would be of little use, not to mention suffering from lack of light.

One last caution I would insert is that lichens are to be avoided if one wishes to maintain a moss terrarium for any length of time. In the moist conditions of confinement, they will soon spread their fungi broadly and overtake the moss, albeit no longer as lichens, but nevertheless encroaching rapidly upon the surfaces of green. If lichens are to be enjoyed in this terrarium, it must by all means be kept open and the mosses provided with water occasionally as needed, perhaps with dry periods, but not too frequently.

I was relieved to read this moss gardener’s treatment of the terrarium. If such an expert as Schenk was able to maintain such a terrarium garden for only three weeks, I felt elated that I, too, had succeeded on occasion to maintain one for so long! In short, if you wish to maintain a terrarium of bryophytes for a lengthy period of time, my best advice to you is Good Luck!

Echoing the comments above, David Wagner (Bryonet 23 June 2013) suggested that the problem with terraria is that they are usually closed containers. He has observed mosses doing well for several years in an open water table where water flowed across the water table. This depends on water that is low in dissolved minerals and may require a filtering system on tap water. One danger in closed terraria, especially small ones, is that the enclosed humidity and lack of air movement encourages the growth of fungi and soon they take over.

Alison Downing (Bryonet 23 June 2013) reported success in growing bryophytes for display by using fish tanks for the mesic species. She attributed the success to using water from a garden pond, citing high levels of chlorine in tap water as a possible source of bryophyte collapse. Nevertheless, these bryophytes in the aquaria also have a limited life.

Ben Tan (Bryonet 23 June 2013) found that bryophytes transplanted to a closed terrarium usually survived from 6-18 months. Even on moss walls, the bryophytes needed complete replacement every two years to maintain aesthetic appeal. This is with no fertilizer, watered with tap water, in a fully air-conditioned room. Even *Bryum* (Figure 93) and *Hyophila* (Figure 111) last only about one year in a self-contained environment indoors with proper light and high humidity.

Alison Dibble (Bryonet June 2013) reports better success. She grows bryophytes on the windowsill all winter in small bonsai dishes. Others are in clear plastic boxes or a clear glass container with a loose-fitting lid. If the container is open, Dibble soaks the mosses in the sink once a week. In the summer she puts them outside under the overhang of a north-facing boulder and lets nature do the watering, but if there is a dry spell she waters them. Using this method, she has kept one bottle of mosses, including *Sphagnum* (Figure 1), for more than three years. And even in a terrarium there is competition. Her *Saelania glaucescens* (Figure 112) had been growing well for five years, but *Mnium* (Figure 113) began to overtake it.

![Figure 111. *Hyophila involuta*, in a genus that lasts about one year in a terrarium. Photo by Michael Lüth, with permission.](image1)

![Figure 112. *Saelania glaucescens*, a moss that has survived a terrarium for five years, but that is being overtaken by *Mnium*. Photo by Janice Glime.](image2)

![Figure 113. *Mnium marginatum* overgrowing other mosses, a problem it can cause in a terrarium. Photo by Jan-Peter Frahm, with permission.](image3)
Appropriate moisture levels are clearly a problem. Yoest (2011) suggests that if mosses and flowering plants or other tracheophytes are to co-exist, one must periodically remove the covering to water the tracheophytes. Keep the cover off for a day or two to allow excess water to escape. When you return the lid, check for condensation and vent the container until you achieve the right balance. In a dish garden or terrarium, proper drainage is needed, so putting pebbles on the bottom can help. Contrary to what most people might expect, the humidity level must be kept low. This condition can often be achieved by using a cover with a small opening at the top.

As an alternative, David Spain (in Yoest 2011) suggests removing the cover in the daytime and covering it at night. He has created a terrarium with a tall cover over a dish, using this routine. The terrarium has the fern ebony spleenwort (*Asplenium platyneuron*; Figure 114) and the mosses *Dicranum scoparium* (Figure 4), *Leucobryum glaucum* (Figure 27), *Hypnum imponens* (Figure 15-Figure 16), and *Campylopus introflexus* (Figure 71). (Be careful with the latter – it is an invasive species, so don’t just throw it outside when you no longer want it.) Another of Spain’s favorites is the moss *Climacium americanum* (Figure 115). Spain concludes that "mosses do not make ideal terrarium plants."

### Bryophytes as Pests

Sadly, bryophytes can even be considered to be pests in gardens and flower pots (*e.g.* Newby et al. 2007). Greenhouse managers are often dismayed at having the invasion of *Marchantia polymorpha* (Figure 116) in many of their flower pots. But it is their method of watering that distributes this liverwort everywhere. The heavy force of water from a hose propels the gemmae out of their cups and onto bare soil nearby. These liverworts often arrive in the greenhouse initially as free-loading passengers in flower pots of new flowers or ferns, either as plants or as gemmae. And the greenhouse satisfies their growing needs.

![Figure 114. *Asplenium platyneuron*, a fern that survives in a terrarium that is opened daily and closed at night. Photo by F. B. Matos, through Creative Commons.](image1)

![Figure 115. *Climacium americanum* with capsules in moss garden, a species that looks good in a terrarium. Photo by Janice Glime.](image2)

![Figure 116. *Marchantia polymorpha* with gemmae cups. Gemmae are splashed about in greenhouses when plants are watered. Photo by David T. Holyoak, with permission.](image3)
Another species known throughout most of North America only in greenhouses is the thallose liverwort *Lunularia cruciata* (Figure 117). Like species of *Marchantia* (Figure 116), it produces gemma in cups, in this case crescent-shaped cups, and these likewise are easily dispersed by typical greenhouse watering methods.

Other volunteers that I have observed include *Bryum* spp. (Figure 64, Figure 93), *Leptobryum pyriforme* (Figure 72), and *Ceratodon purpureus* (Figure 105). These are all mosses, with the latter two frequently producing numerous capsules and thus most likely spreading by spores. *Bryum argenteum* (Figure 64) has detachable terminal buds that will grow new plants. It is likely that it benefits in the same way as the gemmae of the two liverwort species.

A final caution is appropriate. Some bryophytes are invasive, although much less so than their flowering plant counterparts. Nevertheless, they can disrupt ecosystems, changing the success of seed germination, affecting the invertebrates that live there, and changing the hydrology. In addition to the ones that like to travel among flower pots, the most invasive and widespread of these are *Campylopus introflexus* (Figure 71), *Eurhynchium praelongum* (Figure 118), *Lunularia cruciata* (Figure 117), *Orthodontium lineare* (Figure 119), *Pseudoscleropodium purum* (Figure 120), and *Lophocolea semiteres* (Figure 121) (Essl et al. 2013; Mateo et al. 2015). Some of these have spread due to their use as packing material, especially for shipping plants in the horticultural industry.

**Summary**

Peat mosses have been widely used in horticulture as soil additives, and for bedding, as well as forming the foundation for topiary, wreaths, and hanging baskets. Their ability to add moisture makes them ideal as a shipping medium for plants.
Peat mosses are used as soil conditioners, providing a holding medium for nutrients, releasing them slowly following drying. They provide good compost, especially when mixed with such waste products as fish offal or sewage. Some peat mosses provide additional fixed nitrogen through their Cyanobacteria flora. Their antibiotic properties discourage damping-off fungal growth while maintaining moisture. These same properties make them good for air layering. All of these properties make peat mosses good culture media and potting mixes, but other relatively dense mosses work well also.

Peat mosses have been used in forestry to culture young seedlings and in the food industry to culture mushrooms and morels.

Small mosses work well in container gardens such as bonsai and bonkei, where various species are used to simulate different aspects of miniature landscapes. Terraria are more difficult, with mold being a frequent problem. Aeration is important, as is the choice of mosses.

Some species are pests in greenhouses, sometimes being dispersed as gemmae. The watering techniques make gemmae and other detachable parts airborne.

**Acknowledgments**

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**Literature Cited**


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GARDENING: JAPANESE MOSS GARDENS

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CHAPTER 7-2
GARDENING: JAPANESE MOSS GARDENS

Moss Gardens

It is the end of a hectic week and your mind is racing between projects nagging to be finished before another set entreats you. The afternoon hour is late and Friday traffic winds about you in the fury to be somewhere else. Children shout and horns warn of impending danger, or just impatience. You turn the corner and park in the only remaining spot next to the shrouded garden. The Japanese have taught us how to construct a fence that deflects the city's clamor, creating a refuge from the turmoil that bombards our daily lives. But within that fence, in the midst of the city, is a garden – a moss garden. Barely 50 meters on a side, the garden is a far away and peaceful world. Here all seems to melt away as the soft mountains in the distance, created by gentle hills of moss, blend into the quiet fields of green before us. At last we can relax. In such a setting, we can reflect on all that is beautiful and calm.

For the caretaker of this garden, be it large or small, it certainly requires an understanding of mosses in all their ecological and physiological glory. Although the Japanese have been successful for centuries, moss gardening is no small challenge.

Japanese Moss Gardens

Perhaps originating in their present usage during Japan's feudal era (12th-19th centuries), mosses have become a part of Japanese tradition (Schenk 1997). In Japanese, *koke* means moss and *dera* means temple, hence the name of the moss temple *kokedera* (Figure 1). However, as far back as a thousand years ago the Zen Buddhist monks wrote of the mosses in their temple gardens. Yet the rest of the world is just beginning to understand and copy the tranquility of the moss garden.

Bryophytes have always been greatly appreciated as a precious attribute in Japanese gardens (Figure 1). Some of the Japanese gardens are known from as early as the 7th
The earliest of these were based on the T'ang China gardens, but they soon developed their own character, resembling the Japanese landscape. The theme generally reflects the Japanese religion of Shinto, wherein the world is viewed as "infused with the primeval forces of creation" (Seike et al. 1980).

By the fifteenth and sixteenth centuries, the scale of the gardens was smaller, opening the way for miniature plants such as bryophytes to provide the feeling of expanse. Natural features such as ponds and waterfalls were represented by stone and gravel (Figure 2). Unlike gardens throughout most of the world, the Japanese garden is ruled by simplicity. Following this theme of tranquility, the garden must not appear manicured, but rather must maintain a natural look, as in Figure 3. For this reason, as the gardens became the setting for the tea ceremony, they also continued this tradition of a natural look. To avoid the austerity of too much care, the Tea Masters considered the most appropriate caretakers to be old men (Figure 4) and boys who would not be too painstaking in their care to sweep and clean the garden. Having leaves tucked among the rocks or at the bases of trees provides interest (A. L. Sadler in Seike et al. 1980).

Courtyard gardens (Figure 6-Figure 7) are small and provide a relaxing view from a window or doorway. Generally only a few plants provide highlights to an arrangement of gravel and rocks. Mosses may be used here to make a green layer on the ground, or may be islands in a bed of gravel (Figure 8) that simulates the sea or a pond (Seike et al. 1980). In even larger courtyards and many moss gardens, the pond may be real, with koi swimming about (Figure 9).

Public gardens often have a gate at the entrance. Even these offer serenity and often have bryophytes growing on the roof of the gate (Figure 5). The gate gives one the impression of shutting out the world of work, noise, and traffic.
Sand is used in many of the gardens. It is always well kept, often raked with the ridges of raking forming various designs (Figure 10-Figure 12). Some of these simulate a lake with islands and mountains (Figure 10). In other cases, the mosses surround a gravel bed shaped to resemble a lake (Figure 11). The mosses are not arranged in rectangular plots so common to western gardens, but rather typically follow a circular theme. Species of *Polytrichum* (Figure 12) are often used for these islands to break up the bright appearance of the sand (Saito 1980).
18) or a basin for washing one's hands (Figure 19-Figure 20). A small garden, such as most courtyard gardens, will typically have a single plant or one of the above objects as its point of focus.

Figure 13. Stone path in moss garden. Photo by Szabolcs Arany, through Creative Commons.

Figure 14. Kanazawa, Japan – Nagamachi samurai district, house garden walk, demonstrating a straight path with multiple sizes of stones, giving a sense of meandering. Photo courtesy of Elin LeClaire.

Figure 15. A rock bridge retains a natural look in this moss garden and pond at Ginkakuji, Kyoto, Japan. Photo by Janice Glime.

Figure 16. Shrine and pond with stone lamp (foreground), Kyoto, Japan. Photo by Janice Glime.

Figure 17. Nagoya Private Moss Garden with stone lantern as a point of focus. Photo by Janice Glime.
Among the larger gardens, one may see, instead of mosses mimicking the mountains, that shrubs mimic the mosses (Figure 21). In these gardens, the shrubs are cut into rounded forms that look like moss-covered rocks, cascading down a hillside, and sometimes with a small stream or waterfall in their midst. Waterfalls are common in the larger gardens, but occasionally even in very small ones (Figure 22-Figure 24).
Many attractive moss gardens are seen in Kyoto, the ancient capital city of Japan, where the surrounding mountains ensure constant humidity, and prolonged summer rainy seasons favor growth and survival of the mosses. Perhaps the most popular Kokedera, or Moss Temple, is the Koinzan Saihoji Temple (Figure 21) located at the foot of Mt. Koinzan in the west of Kyoto City. There are 92 different species there, each with its own required environmental conditions (Figure 25).

Types of Japanese Moss Gardens

Generally there are three types of Japanese moss gardens: the flat garden (Figure 26) “for contemplation and meditation,” the Tea Ceremony garden (Figure 27-Figure 28) that must convey the feeling of simplicity and seclusion, and both the oldest and most widely appreciated – the hill and pond garden (Figure 29-Figure 31). A roofed courtyard or indoor garden may provide a tea table and cushions for a tea ceremony. The hill and pond gardens resemble the natural landscapes of Japan in simplified form (Avery 1966). They may have bridges, often not straight (Figure 32), forcing the visitor to walk slowly and enjoy the garden. The use of rocks to portray mountains or add a focus point (Figure 33), ponds as oceans or lakes (Figure 25), and bryophytes as the foliage are the essence of traditional Japanese gardens where flowers, per se, are of lesser importance; a green garden, unlike ephemeral flowers, symbolizes long life and offers a place for relaxation and contemplation. In sharp contrast to the myriad of colors and shapes in a traditional American or European garden, the moss garden allures with its subtle shades of green, accented here and there with a rock or group of rocks (Figure 34), a bamboo fountain (Figure 35), a lamp (Figure 36), or an occasional small flowering shrub (Figure 37).
Figure 26. Ryoanji Temple garden in Kyoto, Japan, representing the flat garden. Photo by Janice Glime.

Figure 27. Japanese Tea Garden in San Francisco, CA, USA. Photo by Redheadredflip, through Creative Commons.

Figure 29. Kanazawa Kenroku-en Garden in Japan, an example of a hill and pond garden. Note the lamp that adds a point of focus. Photo courtesy of Elin LeClaire.

Figure 28. The same Japanese Tea Garden, San Francisco, CA, USA, as in Figure 27, but with the azaleas in full bloom. Photo by Caroline Culler, through Creative Commons.

Figure 30. Kyoto Nijo Castle, Shogun's palace garden, illustrating the hill and pond garden with mosses and stones. Photo by Elin LeClaire.

Figure 31. Kokedera Pond in Kyoto, Japan, an example of a hill and pond garden. Photo by Janice Glime.
Figure 32. Kanazawa Kenroku-en Garden in Japan, showing a meandering bridge that forces the visitor to slow down. Photo courtesy of Elin LeClaire.

Figure 33. Boulders add interest to this moss garden at the Saihoji Kokedera in Kyoto, Japan. Photo by Janice Glime.

Figure 34. Kyoto Nijo Castle garden with rocks, Shogun's residence. Photo by Elin LeClaire.

Figure 35. Bamboo fountain in moss garden, a point of interest and focus. Photo by Jeff Kramer, through Creative Commons.

Figure 36. Kanazawa - Nagamachi samurai district, house garden with lamp. Stone lamps are common in Japanese gardens. Photo by courtesy of Elin LeClaire.
Imagine yourself sitting alone in a Japanese spa perched near the top of a mountainside overlooking a green valley untouched by habitation. On every side of the valley are mountains and boulders – as far as you can see. All is peaceful and you are able to relax your eyes and your body. Thousands of Japanese seek just such retreats every year to take them away from the stresses of daily life. Among the most ancient uses of mosses that has persisted into modern life is the design of moss gardens to create that same feeling of distance, lack of commercial clutter, and tranquility of spirit. By using rocks and tiny plants such as mosses, the Japanese create in miniature those scenes that they crave in nature. Even in the space of a few feet in a dooryard or window garden in a city, they often create such an illusion of distant mountains, dry stream beds, and green forests (Figure 38). The Japanese Zen scholars have philosophical ideas about landscapes, and about simplicity and repose, which they try to express in their traditional gardens (Fletcher 1991). While the space in the gardens is usually small, they may try to create an atmosphere of being deep within the mountains and provide a feeling of tranquility. Japanese gardening is not a mere imitation of nature; perhaps "borrowed scenery" is a more appropriate description (Avery 1966) for the attempt to alleviate the drabness of city life. Contemporary Zen scholars contend that many such gardens represent the best in abstract art (Avery 1966).

Dangers to Gardens

These ancient gardens suffer new dangers in our modern society. Kyoto is the city of moss gardens (Figure 40-Figure 56), especially temple gardens. But even restaurants and private residences share in the serenity with their own small gardens. Aside from the effects of trampling from the ever-increasing population of visitors, the fumes of cars and busses have taken their toll. The pollution from these visitor vehicles has forced the closing of Saihoji in Kyoto to the casual visitor, requiring reservations in advance and forcing visitors to park at the bottom of the hill and walk up to avoid further damage from air pollution.

Even bowls (Figure 39) and other objects in the gardens are likely to be covered in mosses, softening the lines and giving a quiet, cool appearance.
Figure 41. This pond in the moss garden at the Saihoji Kokedera (moss temple) in Kyoto, Japan, gives a natural look and one of distance. Photo by Janice Glime.

Figure 42. This pond with a small island and surrounded with mosses at the Saihoji Kokedera in Kyoto, Japan, gives the illusion of a lake. Photo by Janice Glime.

Figure 43. Several mosses provide subtle color differences in this moss garden at Saihoji Kokedera in Kyoto, Japan. Photo by Janice Glime.

Figure 44. This Ginkakuji Temple (Silver Temple) overlooks moss gardens in Kyoto, Japan. Photo by Janice Glime.

Figure 45. A small river provides a natural setting in this moss garden at Ginkakuji in Kyoto, Japan. Photo by Janice Glime.

Figure 46. Here sand forms a volcano (mid right) and mosses miniaturize the landscape at the Ginkakuji shrine in Kyoto, Japan. Photo by Janice Glime.
Figure 47. This path through the moss garden at Ginkakuji Temple in Kyoto, Japan, retains a natural appearance. Photo by Janice Glime.

Figure 48. This moss garden at Ginkakuji Temple in Kyoto, Japan, has depth provided by the pond. Photo by Janice Glime.

Figure 49. Sand is used for dry stream beds and unused paths in moss gardens such as this one at Ginkakuji Temple in Kyoto, Japan. Photo by Janice Glime.

Figure 50. This moss garden at Ginkakuji (Silver Temple) garden in Kyoto, Japan, maintains a natural look. Photo by Janice Glime.

Figure 51. This educational display is labelled VIP mosses. Each is labelled with its Japanese name. These VIP mosses are among the most important ones in the moss garden at the Ginkakuji Temple in Kyoto. Photo courtesy of Onno Muller.

Educational Gardens

One unusual feature at the Ginkakuji (Silver Temple) garden in Kyoto is that it attempts to teach the public about the mosses. In Japan, each species has a Japanese name, and like birds and flowering plants, mosses are known by these names. However, the bryologists know both the scientific names and Japanese names of the mosses. The displays of mosses provide an explanation of their utility to the gardens, showing the most important species (Figure 51, Figure 52). The "interrupter" mosses are "undesirable" mosses that must be weeded out (Figure 53). Among these are non-weedy things, but nevertheless undesirable ones, often for aesthetic reasons. To our surprise, this included *Andreaea* (Figure 54) because of its nearly black (and undesirable) color. Heinjo During, with the help of his students, attempted to interpret the Japanese names into their proper Latin ones, giving us a list of important temple garden species (Figure 55).
Figure 52. These mosses, also on educational display at the Ginkakuji Temple, are normal inhabitants of the Ginkakuji garden. Photo courtesy of Onno Muller.

Figure 53. This educational display is labelled "the Interrupter Mosses." These are weedy mosses that must be pulled from the gardens to permit the others to survive. Apparently they "interrupt" the tranquility. Photo courtesy of Onno Muller.

Figure 54. *Andreaea rupestris rupestris*. *Andreaea rupestris var. fauriei* is among the mosses considered undesirable in the Ginkakuji (Silver Temple) garden in Kyoto because of its black color. Photo by Des Callaghan, with permission.

Figure 55. Japanese moss names and Latin names for those in the educational collection in Kyoto. From Heinjo During.
Variations

We must not forget that the Japanese are also creative. While they appreciate the calm of a garden, they do not restrict themselves to the purity of the three garden types mentioned above. The following images illustrate some of that diversity (Figure 57-Figure 63).

Figure 57. Tōfuku-ji, Kyoto, Japan. This formal pattern looks like a mix of western and Japanese design. Photo from Wikimedia Commons.

Figure 58. Here the meandering path takes on a different form in the Rhododendron garden with mosses playing a minor role. Photo by Monty Monsees, through Creative Commons.

Figure 59. Ankokuji garden in Hiroshima, Japan, giving a natural appearance but with rocks providing the major feature. Photo from Wikimedia Commons.

Figure 60. Kanazawa Kenroku-en Garden showing the famous koto-fret stone lantern. The bamboo fence is also a common feature in Japanese gardens. Photo courtesy of Elin LeClaire.

Figure 61. Courtyard garden of a former geisha house in Kanazawa, Ishikawa, Japan – straw protects trees from snow. But even that protection is artistic, natural, and restful. Photo from Wikimedia Commons.
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Figure 62. Ginkakuji Moss Garden pool in Kyoto, Japan, with coins, a practice that may have originated in western countries. Photo by Janice Glime.

Figure 63. The mosses in this Japanese garden near Columbus, Ohio, USA, do not quite reach the restful landscape achieved in most of the Japanese gardens. This may be partly due to the lack of a rainy season and the land-bound location. Photo by Janice Glime.

**Charcoal Gardens**

Nancy Church provided me with images of the charcoal gardens (Figure 64-Figure 66) in which moss gardeners used charcoal, providing highlights. The small black pieces with lines are charcoal, a feature that Nancy considered to be beautiful and amazing.

Figure 64. Japanese charcoal and moss garden. Photo by Amy Laudenslager through Nancy Church.

Figure 65. Japanese charcoal and moss garden. Photo by Amy Laudenslager, through Nancy Church.

Figure 66. Japanese charcoal and moss gardens. Photo by Amy Laudenslager, through Nancy Church.

**Dominant Species**

Although many species are used, a few dominate the gardens, especially the private gardens. One of the most common is *Polytrichum* (Figure 67-Figure 71). This is most likely because it does well in the conditions of the garden and is easier to transplant than most (personal experience). *Leucobryum* (Figure 72-Figure 74) is used frequently, despite its narrower requirements (it seems to be a problem to cultivate in the USA according to my friends and my own experience). Perhaps the Japanese species are easier to grow than ours. But its endearing quality is its beautiful, pale cushions. It creates a restful landscape.
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Figure 67. Ginkakuji Moss Garden, Kyoto, with a carpet of *Polytrichum*. Photo by Janice Glime.

Figure 68. Kanazawa Kenroku-en Garden in Japan with lawn of *Polytrichum*. Photo courtesy of Elin LeClaire.

Figure 69. Kanazawa Kenroku-en Garden with *Polytrichaceae*. Photo courtesy of Elin LeClaire.

Figure 70. Kanazawa Kenroku-en Garden in Japan, with a *Polytrichum* lawn and stone lantern. Photo courtesy of Elin LeClaire.

Figure 71. *Polytrichum commune* in a small garden at the entrance to the Japanese Cake Shop in Hiroshima, Japan. Photo courtesy of Hironori Deguchi.

Figure 72. *Leucobryum* spills down a slope in a moss garden at the Saihoji Kokedera (moss temple) in Kyoto, Japan. Photo by Janice Glime.
Summary

Moss gardens are known for their serenity, emphasizing simple shades of green with only occasional color from shrubs or other flowers. Mosses are used to miniaturize the landscape, giving the feeling of distance. They have been a part of Japanese tradition since the feudal era.

There are three basic types of Japanese moss gardens: flat gardens, Tea Ceremony gardens, and pool and mountain gardens. In addition, sand gardens are often combined with moss gardens, often simulating lakes or streams. A number of variants exist, including the charcoal garden.

Even private homes, restaurants, and other shopkeepers maintain small moss gardens, especially where they can be viewed from within the building. The greatest number of moss gardens is in the city of Kyoto. The primary mosses used are species of *Polytrichum* and *Leucobryum*, but some gardens have nearly 100 species.

Acknowledgments

Heinjo During kindly sent me the pictures and gained the permission for me to use the educational pictures taken by his student, Onno Muller, illustrating the educational displays at the gardens at Ginkakuji, Kyoto, Japan. He and his students translated the Japanese names into the Latin names.

Literature Cited


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GARDENING: PRIVATE MOSS GARDENS

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CHAPTER 7-3
GARDENING: PRIVATE MOSS GARDENS

Private Gardens

Private gardens are gaining popularity in the USA (Dunn 2008; Martin 2008; Cullina 2009). You know moss gardens are coming of age when an article appears in the New York Times (see Tortorella 2014). Garden journals give advice on establishment and care of moss gardens. But what works in one part of the world may not work in another, and that is true within countries as well. Watering instructions and species choice must be in tune with local climate, light, available bryophytes, and competing species.

In Japan, even tiny spaces a meter wide by three meters long are used for a garden. It may be a vegetable garden, but often it is a moss garden with a few tracheophyte highlights (Figure 1). Such private gardens give their owners a sense of space and tranquility (Figure 2). Mosses are particularly enjoyed because they miniaturize the landscape and give a feeling of looking into the distance (Figure 3-Figure 9). Cushions of Leucobryum (Figure 10) can resemble distant mountains. Polytrichum (Figure 11) can simulate a forest. Hypnum imponens (Figure 12), a common "sheet moss" sold for decorative purposes, is used to "fill nooks and crannies" (Cullina 2008). Small mosses in the foreground provide the open fields. Pebbles become boulders.

Figure 1. This is a large private moss garden in Nagoya, Japan, using boulders to add interest. Photo by Janice Glime.

Figure 2. This peaceful scene is a private moss garden in Kyoto, Japan. Photo by Janice Glime.
Figure 3. This lamp adds interest in a private moss garden at a home near Nagoya, Japan. Photo by Janice Glime.

Figure 4. These rocks form a path through *Polytrichum* in a private moss garden in Nagoya, Japan. Picture by Janice Glime.

Figure 5. Fukushima-san sweeping his private moss garden in Nagoya, Japan. Photo by Janice Glime.

Figure 6. This path leads through *Polytrichum* in a private garden in Nagoya, Japan. Photo by Janice Glime.

Figure 7. *Entodon* and *Polytrichum* grow in a private moss garden in Nagoya, Japan. Typically, the *Polytrichum* will outgrow the pleurocarpous mosses such as *Entodon*. Photo by Janice Glime.

Figure 8. This portion of a private moss garden in Nagoya, Japan, has texture created by different species of mosses. Photo by Janice Glime.
Making Your Garden

Private moss gardens are common in Japan (Pullar 1966/1967; Inoue 1980), but elsewhere they are rare. In Chatsworth, Great Britain, there is a moss and lichen garden of 33 moss and 4 liverwort species, including such common taxa as *Dicranella heteromalla* (Figure 13-Figure 14), *Dicranum scoparium* (Figure 15), *Hylocomium splendens* (Figure 16), *Necarea crisp* (Figure 17), *Plagiommium undulatum* (Figure 18), *Polytrichum commune* (Figure 19), *P. piliferum* (Figure 20-Figure 21), *Rhizomnium punctatum* (Figure 22-Figure 23), and *Thamnobryum alopecurum* (Figure 24) (Ando 1972). And where else but at the home of a poet – we find cushions of *Polytrichum commune* adorning the gardens of Poet Laureate W. Wordsworth.
Figure 14. *Dicranella heteromalla* with capsules, showing the hair-like leaves. Photo by Michael Lüth, with permission.

Figure 15. *Dicranum scoparium*, a common species that is used in moss gardens in Europe and the USA. Photo by Janice Glime.

Figure 16. *Hylocomium splendens*, a common northern moss used in European and American moss gardens. Photo by Michael Lüth, with permission.

Figure 17. *Neckera crispa*, a common species in Europe, where it is used in moss gardens. Photo by Michael Lüth, with permission.

Figure 18. *Plagiomnium undulatum*, a common species in Europe, where it is used in moss gardens. Photo by Michael Lüth, with permission.

Figure 19. *Polytrichum commune*, a common species that is used in moss gardens in Europe and the USA. Photo by David Holyoak, with permission.
In the Netherlands, a Japanese garden at the estate of Clingendael has become a moss garden. It sports several locally rare species [the leafy liverworts *Odontoschisma denudatum* (Figure 25) and *Plagiochila asplenioides* (Figure 26)] among its 57 taxa. Schoenmakers (1985) speculates that several of the species that are restricted to paths are the inadvertent contributions of visitors.
Mossery

In the 19th Century, a number of British and Americans joined the fad of moss collecting (Wikipedia 2017). This interest led to the establishment of mosseries in a number of both British and American gardens. Mosseries are typically made with slatted wood, with a flat roof. They are open to the north, permitting the entrance of light while maintaining shade. Moss samples were installed in the cracks between the wooden slats. Regular moistening of the entire structure helped to maintain growth.

Garden Variety

In the United States, mosses are being used as a means of exploring new garden themes (Massie 1996). A number of web sites give instructions for planting moss gardens, often supplying pictures of very small ones to the large ones of Japan. Even in the highly settled New Jersey, one anthropologist maintains an entire acre of moss (Whiteside 1987). And the prestigious journal Horticulture sports one article titled "Even a rolling stone could get some moss here" (Atkinson 1990).

In spite of the presence of moss gardens in the United States at least as early as the 1930’s (at Cutting Estate, Great River, Long Island, N.Y.; Grout 1931), few suppliers provide a selection of mosses. Atkinson (1990) complained that when inquiring of the editor of a horticulture magazine where one could obtain mosses for gardens he was referred to Carolina Biological Supply! Nevertheless, more recently a quick search on the web revealed several sources for Atrichum (Figure 27), Callicladium (Figure 28), Dicranum scoparium (Figure 15), Campylopus (Figure 29), Hypnum imponens (Figure 12), Thuidium delicatulum (Figure 30), Leucobryum (Figure 10), Climacium dendroides (Figure 31), Dicranella heteromalla (Figure 13-Figure 14), and Plagiomnium cuspidatum (Figure 32). One site sold sheet moss that had been cleaned, spread on a backing, glued down, and dyed green! No, thank you! Another source offers a complete garden, including 400 sq feet of moss, for $US 399.99.
changes among the mosses, just as in planting a flower garden. This can provide highlights in different places as the garden changes through the growing season.

Mosses have life cycles that change their appearance. Spring is a typical season for the production of antheridial splash cups. In some species these are reddish (Figure 20); in others, especially splash platforms, they are green, but look like green flowers (Figure 33). Others have colorful setae (Figure 34, Figure 36) and capsules (Figure 35-Figure 37), and these can appear throughout the summer and autumn, depending on the species.

**Seasons**

To maintain variations in color through the growing season, one needs to pay attention to the phenological

Figure 30. *Thuidium delicatulum*, a moss that does well in American moss gardens. Photo by Janice Glime.

Figure 31. *Cladonia dendroides*, a moss often used in American moss gardens. Photo by Janice Glime.

Figure 32. *Plagiomnium cuspidatum*, a common species in American moss gardens, often as a volunteer. Photo by Janice Glime.

Figure 33. *Rhizomnium punctatum* males showing splash platforms that look like green flowers. Photo by Michael Lüth, with permission.

Figure 34. *Ceratodon purpureus* showing red-tipped setae in early spring. Photo by Hermann Schachner, through Creative Commons.

Figure 35. *Ceratodon purpureus*, showing red capsules in early summer. Photo by Michael Lüth, with permission.
Many bryophytes like a damp habitat (Figure 38). And some of these habitats are very poor in nutrients. Hence, the bryophytes are naturals for water gardens (Figure 39-Figure 40) (Freiland 2017).

Among the many aquatic species, one of the best for a garden is *Philonotis fontana* (Figure 41). It has a fresh, pale green color and tolerates partial submersion or soggy ground.
Bog Garden

Gardeners such as Case (1994) have found *Sphagnum* (Figure 42) bog gardens to be a viable alternative in the Great Lakes area, avoiding high maintenance problems of woodland species unsuited for residential living. These require special conditions devoid of limestone rock and chlorine.

The RaisingRarities website (<http://raisingrarities.com/bog-garden/>) provides instructions for preparing a bog garden. The pond is excavated and a pond liner is used to cover the shape (Figure 43). It can have a pool attached, as in the diagram, but will require a shallow section for the bog (Figure 44). The lining at the lip of the bog area keeps sand from entering the deeper pool and should go up the bog side of the stones and under them (Figure 45). The bog shelf should be filled 2.5-5 cm deep with pure silica sand. Plant *Sphagnum* (Figure 42) on the bog shelf and fill the entire shelf with it. Pitcher plants and sundews can be added for interest, planted among the *Sphagnum*. Collect rainwater and use it to keep the pond and bog at a constant level.
My Personal Garden

For my own moss garden, I managed to rescue *Marchantia polymorpha* (Figure 46; with gemmae cups) that was being overtaken by lawn grass on the university campus. It started as a small clump, but one day only a few weeks later I found tiny grey-green specks all over my bare soil (I was just starting the garden). On closer inspection, I found these to be germinating gemmae – the liverwort had spread all over the bare surface and was invading my dying *Leucobryum* (Figure 10) cushion as well. By the second year, I had several forests of archegoniophores (Figure 47), but it seems I didn't get any males.

Figure 46. My moss garden initially had a small patch of *Marchantia polymorpha*, about 10 cm in diameter. Within a month, it spread by gemmae, extending about a half meter in each direction. Photo by Michael Lüth, with permission.

Figure 47. The second year these *Marchantia* plants produced archegoniophores in abundance. After a few years, I had to remove some of the *Marchantia* to provide space for mosses. Photo by Janice Glime.

Added to that were *Fissidens* (Figure 48), *Brachythecium* (Figure 49), *Climacium dendroides* (Figure 31), *Dicranum scoparium* (Figure 15), *Leucobryum glaucum* (Figure 10), *Plagiomnium cuspidatum* (Figure 32), *Polytrichum juniperinum* (Figure 50), *Rhytidadelphus triquetris* (Figure 51), *Barbula* (Figure 52), *Thuidium delicatulum* (Figure 30), and *Ceratodon purpureus* (Figure 34) that I was able to collect locally, mostly in places where they were doomed to be overgrown or destroyed by traffic. Of these, *Fissidens*, *Plagiomnium cuspidatum*, and *Thuidium delicatulum* (Figure 30) were the most successful.

Figure 48. *Fissidens taxifolius* with capsules; some species of *Fissidens* grow easily in moss gardens in North America. Photo by Keith Bowman, with permission.

Figure 49. *Brachythecium salebrosum*, a species that can occur in large mats usable for moss gardens. Photo by Michael Lüth, with permission.

Figure 50. *Polytrichum juniperinum* with capsules in moss garden in Michigan, USA. Photo by Janice Glime.
Figure 51. *Rhytidiadelphus triquetrus*, a species that often grows well in moss gardens in North America. Photo by Janice Glime.

Figure 52. *Barbula unguiculata*, a hardy species that adds a contrasting color in the moss garden, preferring a sunny site. Photo by Michael Lüth, with permission.

The *Leucobryum glaucum* (Figure 10) was a gift from a friend, and it fared well the first year. It looked bad when winter ended and stains of tannic acid from leaf litter discolored it. It survived, but not well, so the next year I made sure it was not covered with litter for the winter, but it did not make it. I replaced it with a really nice hummock of *L. glaucum*. This time I put it on a bed of pine needles, a substrate it often has in nature. But it wasn't long before the chipmunks decided that made a nice entrance to their tunnel.

Some night-active animal also tore up all the *Dicranum scoparium* (Figure 15) and *Thuidium delicatulum* (Figure 30) the first night, and once dismembered from their normal growth habit, both failed to thrive. However, later introductions have survived winter and both have produced new growth, so there is hope. Some rodent decided that the *Thuidium* patch was the best place to enter its underground passage, but I seem to have thwarted that hole by stepping on it and filling it in. Alas, now there is a hole in the *Polytrichum* patch.

Most of the *Polytrichum juniperinum* (Figure 50) is doing fine (Figure 53). It is only the large patch that didn't have good structural integrity that looks like a fallen forest. But even there a few die-hards are putting up new shoots.

Figure 53. My personal moss garden, when it was about three years old, in Houghton, Michigan, USA. Photo by Janice Glime.

The real winners [*Marchantia* (Figure 46-Figure 47) aside] are *Fissidens* (Figure 48) and *Plagiomnium cuspidatum* (Figure 32), with the latter looking a luscious bright green. To my surprise, the *Rhytidiadelphus triquetrus* (Figure 51) did well, whereas *Hylocomium splendens* (Figure 16) didn't like its transplant at all. One patch of *Climacium dendroides* (Figure 31) had mostly brown plants with a few new green shoots arising, but the second patch eventually sprang to life, producing a solid cushion of plants of a most vital green. The old, weedy *Ceratodon purpureus* (Figure 34) seems not to like my gardens much and disappears rather rapidly.

A new patch of the liverwort *Conocephalum conicum* (Figure 54) seems to be doing well. It, and *Fissidens* (Figure 48), also fared well in my indoor garden. That is, they fared well until the birds ate the *Conocephalum*. I found it with triangular cuts around the edge. Each day it grew smaller until it disappeared. The *Fissidens* diminished and ultimately disappeared after the box turtle died. Apparently the turtle had been an effective dispersal agent for both species because they kept appearing in new places until after the turtle died.

Figure 54. *Conocephalum conicum*, a rock and soil dweller that adds interesting texture to a moss garden. Photo by Robert Klips, with permission.

I attribute my success, after several failures, to the installation of a sprinkling system. It comes on about 4 am for 20 minutes each night. (We usually don't get much rain in spring or summer.) That makes it hydrated and ready to
I have learned that leaf litter apparently creates more problems than just deprivation of light during the growing season. The tannic acid seems detrimental to several species, because even when I remove the litter the day the snow retreats from its surface, the mosses that were covered with it seem to have suffered. When I removed most of the leaves before winter, the mosses seemed to fare much better.

Mountain Moss Enterprises

The Mountain Moss Enterprises is located near Revard, North Carolina, USA, and is owned by Annie Martin. Known as Mossin' Annie, this entrepreneur has dedicated her life to rescuing bryophytes that are in the path of destruction due to construction or other human activities. These mosses she either plants in one of her many projects, both public and private, or in her own garden where she cares for them until they meet their destiny in a moss garden somewhere.

One of the frequent sources of her bryophytes is from overgrown blacktop. This seemingly unlikely habitat can be a good source for large patches of bryophytes that come in large sheets. Others come from roofs where the owners are convinced they are harmful.

Martin lives in an area of the Appalachians that receives 150-200 cm rainfall per year (Tortorella 2014). Nevertheless, she waters her moss gardens three times each day. She claims that with 3-4 minutes of supplemental water per day the mosses will grow year-round in "nearly any temperature." (I can't imagine that watering when they are under snow is helpful. It would most likely create ice that could actually dry them out more.)

Mosses can dry out or freeze, and easily survive, green up when once again getting wet, but during that dry period they don't look nice. This ability to dry makes them easy to ship, so the distance to a moss supplier is not a real problem. But obtaining mosses from elsewhere does present ecological problems. In addition to the raping of the landscape by some moss collectors, it introduces non-native species.

Martin makes a variety of designs in her gardens, sometimes using differences in colors of leaves to create designs (Figure 55). In other cases, she may use colorful lichens (Figure 56) or furniture to create highlights (Figure 57).

Figure 55. Moss garden at Mountain Moss Enterprises, Pisgah Forest, North Carolina, USA, August 2009. Photo by Annie Martin.

Figure 56. MountainMoss Enterprises moss arrangement with red cap lichens, Cladonia sp. Photo courtesy of Annie Martin.

Figure 57. Mossin' Annie garden in snow, showing the green of the mosses, even in winter. Photo courtesy of Annie Martin.

Annie Martin (pers. comm. 31 January 2010) received a grant to explore the cultivation of mosses as a cash crop to replace declining tobacco farms. This study involved a partnership of NC Cooperative Extension, Rural Advancement foundation International-USA, and the NC Tobacco Trust Fund Commission which provided the funding. Martin was able to explore various propagation techniques.

Martin points out that moss cultivation requires far less time, labor, and equipment for both maintenance and harvesting compared to tobacco farming. Start-up money is likewise far less for establishing mosses. Maintenance costs are limited to labor and watering, requiring no chemicals, no fertilizers, no pesticides, and no herbicides. This eliminates the pollution of groundwater that is typical of agriculture. On the other hand, the mosses in the Southeast can be harvested any time of year, with their productivity measured in square feet.

Moss and Stone Gardens

David Spain is the owner of Moss and Stone Gardens in Raleigh, North Carolina, USA (Tortorella 2014). Spain presented moss gardening on the Martha Stewart Show, reporting that "she was a big moss fanatic." Spain recounts his early attempts to grow mosses, bemoaning the lack of teachers or sources appropriate for the area. One of these early attempts, following online advice, was to make a mix of mosses in a blender with buttermilk. This slurry was...
painted onto rocks or soil. Instead of a moss garden, he got a mold garden. His garden designs tend to mimic nature (Figure 85-Figure 87).

Dale Sievert's Garden

Dale Sievert is a landscape gardener in Wisconsin. He became enamored with mosses and now his property is adorned with 60 species of bryophytes. Some of these species arrived by themselves. Among the more common ones in the garden are *Bryum caespiticium* (a widespread species; Figure 59), *Thuidium delicatulum* (a species that spreads rapidly; Figure 60), *Rhodobryum ontariense* (an interesting species that resembles miniature palm trees; Figure 61), *Plagiomnium cuspidatum* (a species that commonly volunteers; Figure 62), *Leucobryum glaucum* (a cushion moss that prefers acidic soil; Figure 64), and *Anomodon rostratus* (a very common species locally and in his garden; Figure 76).

Sometimes Sievert lets the mosses determine their own successional pathway. As is typical, pleurocarpous mosses often overrun the acrocarpous mosses (Figure 63). But acrocarpous mosses can invade tight acrocarpous moss cushions as well, as is a common event in which *Polytrichum* invades a *Leucobryum* cushion (Figure 64). A series of pictures demonstrates some of the changes through time, 2011-2015 (Figure 65-Figure 67).
Figure 63. Nature has her own ideas about what belongs where. Here *Atrichum* is being invaded by pleurocarpous mosses. Photo courtesy of Dale Sievert.

Figure 64. *Leucobryum glaucum* with invading *Polytrichum*. Photo courtesy of Dale Sievert.

Figure 65. Moss and cat statues in 2011 showing well-established but still thin mat of mosses. Photo courtesy of Dale Sievert.

Figure 66. Moss and cat statues in 2013 showing thick mat and capsules. Photo courtesy of Dale Sievert.

Figure 67. Moss and cat statues in 2015. The original moss has been replaced with *Thuidium delicatulum* dominating the scene. Photo courtesy of Dale Sievert.

Sievert has a number of special features to highlight the various areas of his garden. A bamboo fountain pours into a small pool surrounded by mosses (Figure 68). A bird bath is adorned by colorful rocks and moss-covered rocks (Figure 69). As in many gardens, including my own, a Japanese lantern adds interest (Figure 70). Small to large boulders can add diversity to the scene and may add their own beauty (Figure 71-Figure 72). Stumps provide flat platforms for miniature gardens (Figure 73-Figure 74) or depressions that have their own interest and are great bryophyte substrates (Figure 75). Statuary peers at the visitors or poses playfully among mosses (Figure 74-Figure 75). Ferns provide changes in texture (Figure 76). Pools can attract frogs (Figure 77).
Figure 68. Bamboo fountain in mossy garden, creating a refreshing pool that raises the humidity for the nearby mosses. Photo courtesy of Dale Sievert.

Figure 69. Birdbath garden in Dale Sievert's moss garden. Photo courtesy of Dale Sievert.

Figure 70. Dale Sievert's moss garden, adorned by a Japanese lamp. Photo courtesy of Dale Sievert.

Figure 71. Rocks and a bit of wood enhance this scene with mostly *Anomodon rostratus*, a common moss in Dale Sievert's garden. Photo courtesy of Dale Sievert.

Figure 72. *Thuidium delicatulum* and rocks in Dale Sievert's moss garden. Photo courtesy of Dale Sievert.

Figure 73. Here a miniature garden grows on a stump in Dale Sievert's moss garden. Photo courtesy of Dale Sievert.
Figure 74. Statuary can add interest or even bring a laugh. Here *Anomodon rostratus* grows with bunnies on a stump. Photo courtesy of Dale Sievert.

Figure 75. Raccoon statues in tree stump bring a smile in the moss garden. Photo courtesy of Dale Sievert.

Figure 76. Even a fern can provide a highlight, seen here hovering over *Anomodon rostratus*. Photo courtesy of Dale Sievert.

Figure 77. Pools can provide habitat and a welcome drink for wildlife. Here the Green Frog *Rana clamitans* sits on a mossy rock. Photo courtesy of Dale Sievert.

Fungi (Figure 78-Figure 79) are willing participants in Dale Sievert's garden. The mosses help to keep the soil moist longer, permitting the fungal threads to thrive. In the right conditions, the fruiting bodies emerge, adding color to the garden.

Figure 78. The pore fungus *Boletus* sp. and moss. Photo courtesy of Dale Sievert.

Figure 79. *Coprinus* with the moss *Anomodon rostratus*. Photo courtesy of Dale Sievert.

Dale has been fortunate to have some of his mosses exhibit prolific "fruiting." The setae and capsules often add brilliant colors to the landscape.
The beauty of a Japanese garden captures the admiration of many moss gardeners. And Dale Sievert's garden has its own Japanese garden section. It is complete with a small pond, bridge, and Japanese lantern (Figure 84).

New Methods in Moss Gardening

Rick Smith (2009) has written one of the North American guides to moss gardening, *New Methods in Moss Gardening*. Smith provides his personal experiences around the world where he has created moss gardens or been a consultant. He provides instructions for growing twelve of the most common mosses, accompanied by pictures (Figure 85-Figure 87).
Harvesting Ban

In 2006, a moratorium was declared on moss harvesting in the national forests around Asheville, North Carolina, USA (Tortorella 2014). This ban was based on a study of the moss trade. Local collectors would sell sheet moss for as little as $.50 per pound to members of the floral trade. But stripping a log of all its moss requires 20 years for a new crop, despite all the local rainfall. Gary Kauffman, an ecologist and researcher on the study, determined that if a third of the moss was left on the log, the mosses would grow back in ten years. One of the dangers of collecting the mosses is what fishermen call "bycatch." Unintended species come along with the desired ones, and some of these are rare and endangered. Including these bycatch species, studies indicate that more than 70 species are harvested in the Appalachian moss industry.

Because of these conservation concerns, it is best to do as Annie Martin has done – rescue mosses and liverworts that are scheduled for destruction. In many of these locations, the moss "invaders" are hardy species and ones likely to survive in a garden.

Summary

Private moss gardens tend to serve the same purpose as the larger moss gardens. Rocks, pebble paths, lamps, and other items add interest, and the limited color gives them a peaceful appeal. Outside of Japan, fewer moss gardens exist, in part because the climate is often not suitable. Another difference seems to be the love of color in other parts of the world.

Mosseseries are an older form of growing mosses. The moss gardens themselves have a wide variety, using artistic designs, Japanese styles, natural styles, and mixed with flowering plants. They vary by season, changing colors when producing reproductive structures and between wet and dry states. Water gardens require different species, but running water can add sound to the landscape. Bog gardens can be used to grow insectivorous plants and other bog plants.

Worldwide, mosses such as *Polytrichum* and *Leucobryum* seem to be popular choices for these gardens. Species like *Thuidium delicatulum*, *Fissidens* sp., and *Plagiomnium cuspidatum* spread easily and may overtake acrocarpous mosses nearby. *Plagiomnium cuspidatum* can often arrive by itself.

Harvesting mosses should only be done on your own property or other private property where you have permission. The best way to get plants is to rescue them where they are scheduled for destruction.

Acknowledgments

I appreciate the email discussions with Nancy Church, Annie Martin, Rick Smith, and David Spain. Most recently, I spent an afternoon discussing mosses and moss gardening with Dale Sievert, leading me to include additional topics in an attempt to answer his questions.
Literature Cited


CHAPTER 7-4
GARDENING: MOSS GARDEN DEVELOPMENT AND MAINTENANCE

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CHAPTER 7-4
GARDENING: MOSS GARDEN
DEVELOPMENT AND MAINTENANCE

Choice of Bryophytes

Careful selection of bryophytes will greatly increase the chances for success. These plants often have niches that are not provided by the typical garden spot, so care should be taken to select species with habitat requirements similar to that available in the garden.

When you collect different species of mosses and then plant them together, the needs of the different species may differ. There are many species and it’s often difficult to discern differences without using a hand lens or consulting a bryologist. If requirements differ, the one most suited can more easily overgrow the other. I suggest that you learn to distinguish the acrocarpous from pleurocarpous species and keep these two separated. The horizontal growth form of pleurocarpous species easily overtakes the upright acrocarpous species.

Most acrocarpous mosses do not like constant moisture whereas most pleurocarpous ones do. One way to deal with this is to maintain a regular watering schedule and allow the mosses that are flourishing to take over the ones that are not. Dead or dying mosses of one species can make a welcoming surface for other mosses to invade or provide suitable substrate for spores to germinate. You can speed up the process by fragmenting some of the flourishing mosses directly on top of the ones that are failing.

In some cases large areas might be transplanted with a moss that is not appropriate for the new conditions and all of the new transplants die. If the area continues to be watered as if the moss is still alive, after several months the spores of another species might germinate on top of the decaying moss and a more appropriate species will develop.
This bed of dead moss retains moisture, controls erosion, and reduces weed invasion. It permits spores of other mosses to have places to land and establish without blowing away. Developing a moss area will eventually lead to some of the species performing better than others and the faster-growing species will subsequently dominate the area.

Spain (2012a) advises that you can "let mother nature decide what species to introduce by clearing the area down to bare earth and then begin watering just as though there was moss already present... If you build it, they will come!"

One might learn from the mosses that are often considered weeds. Charlie Campbell (Bryonet 17 April 2014) found that his parents’ lawn in northern England had *Rhytidiadelphus squarrosus* (Figure 2) as a co-dominant with the grass. *Atrichum undulatum* (Figure 3) and *Plagiomnium undulatum* (Figure 4) also occurred in small patches. In Berkshire, his flats were surrounded by grasslands and were on dry, sandy, open lawn. On the shady side of the flats the *Rhytidiadelphus squarrosus* grew, but on the sunny areas two different communities developed. On the west-facing slope the community was rich in bryophytes, including *Riccia glauca* (Figure 5), *Sphaerocarpos* sp. (Figure 6), *Didymodon vinealis* (Figure 7), and others. On the east-facing side, an abundant *Polytrichum juniperinum* (Figure 8) cover developed. After several days of rain, *Lophocolea bidentata* (Figure 9) became extremely frequent on both sunny sites.

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**Figure 2.** *Rhytidiadelphus squarrosus*, a common moss in lawns in parts of Europe. Photo by Michael Lüth, with permission.

**Figure 3.** *Atrichum undulatum*, a moss that sometimes invades lawns. Photo by Janice Glime.

**Figure 4.** *Plagiomnium undulatum* with ice, a moss that sometimes invades lawns in Europe. Photo by Tim Waters through Creative Commons.

**Figure 5.** *Riccia glauca*, a thallose liverwort that survives on west-facing slopes. Photo by Bernd Haynold, through Creative Commons.

**Figure 6.** *Sphaerocarpos* sp., a liverwort that survives on west-facing slopes. Photo by David T. Holyoak, with permission.
Didymodon vinealis is often found on rooftops, concrete, and rock walls. Photo by Michael Lüth, with permission.

Didymodon vinealis is often found on rooftops, concrete, and rock walls. Photo by Michael Lüth, with permission.

Polytrichum juniperinum, a moss that does well on west-facing slopes. Photo by Jan-Peter Frahm, with permission.

Polytrichum juniperinum, a moss that does well on west-facing slopes. Photo by Jan-Peter Frahm, with permission.

Lophocolea bidentata, a moss that seems to suddenly appear in sunny spots after a rainfall. Photo by Michael Lüth, with permission.

Lophocolea bidentata, a moss that seems to suddenly appear in sunny spots after a rainfall. Photo by Michael Lüth, with permission.

Few published studies have taken an experimental approach to moss gardening, although I'm sure many gardeners have used trial and error to determine the best bryophytes for their gardens. Radu et al. (2016), however, were interested in bryophytes for a variety of applications and set out to determine the most suitable species. They used six species of mosses in hydroponic experiments:

Syntrichia ruralis (Figure 10), Homalothecium sericeum (Figure 11), Ceratodon purpureus (Figure 12), Grimmia pulvinata (Figure 13), Racemiastrum aciculare (Figure 14), and Bryum capillare (Figure 15). These species were tested at different light intensities and water dosing regimes. The researchers concluded that Grimmia pulvinata and Ceratodon purpureus adapted the best to the controlled environment. They thus considered them to be suitable for use in landscape design. But lab conditions are not field conditions, and constant conditions are quite different from constantly varying conditions. The chapter on Phenology in Volume 1 can suggest a few.

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Among the known successful ones are *Marchantia polymorpha* (Figure 16) and *Lunularia cruciata* (Figure 17) on garden paths and damp soil, *Conocephalum conicum* (moist soil; Figure 18), and *Riccia sorocarpa* (Figure 19) and *Riccia glauca* (Figure 5) in damp fields and garden beds (but small and easily overgrown).

**Thallose Liverworts**

One seldom thinks of liverworts in the context of a "moss" garden, but several thallose liverworts are suitable for "moss" gardens. These can be pressed into soft soil so that they have good contact with the substrate (Fletcher 1991).
**Sphagnum – peat mosses**

Most *Sphagnum* (Figure 20) taxa require a wet, acidic habitat, and most have a somewhat narrow range for both of these. Their habitat should be mimicked, and that means that they need to be supplied water from below (Fletcher 1991). This can be accomplished by placing them in flower pots in a shallow tray of standing water. *Sphagnum* is well constructed to soak up and transport the water externally through all the capillary spaces surrounding its stem. The proper pH can be maintained by growing the plants on their own peat. Tap water can easily kill them. If it has many minerals in it, they will accumulate on the surface and eventually kill them. Calcium is particularly lethal to *Sphagnum*. To solve this dilemma, distilled water or rainwater is the best watering medium. No fertilizer is needed, and in fact should be avoided.

Although many *Sphagnum* (Figure 20) species are sun-loving, too much can fry them. Fletcher (1991) reports losing many of his plants during a hot summer when he forgot to move the plants into the shade. The problem is that sun will quickly dry out the plants, and most of the taxa are not drought tolerant. Furthermore, most lack protection against bright sun that can destroy the chlorophyll.

Birds can be a problem in a moss garden. The conditions that favor growth of *Sphagnum* (Figure 20-Figure 21) also favor the presence of a number of invertebrates. Hungry birds, especially early in spring, can be quite disruptive as they rummage for dinner. And nesting can be an even bigger problem, especially if your garden provides lots of mosses in a city area where few other mosses exist. In my indoor garden, mosses and zebra finches simply cannot co-exist. The birds win every time, carrying off every bit of moss for nesting material. Fletcher (1991) suggests covering the mosses with netting to minimize the disturbance. Wire netting must be avoided because it is likely to release zinc or other metal that is toxic to the bryophytes.

Fletcher (1991) suggests *Sphagnum quinquefarium* (Figure 22) for well-drained slopes in wet woods. *Sphagnum cuspidatum* (Figure 23) does well in pools, where it looks like a wet kitten. Fletcher has even kept it in a jam jar for a year. On a bed of peat, *Sphagnum compactum* (Figure 24) can tolerate drying, prefers shade, and does not like being water-logged.
Polytrichum – hairy cap mosses

The most common of the mosses in Japanese gardens (Figure 1) of all kinds is the common hairy cap moss, *Polytrichum* (Figure 25). This group of mosses is common in both temple gardens and private gardens. *Polytrichum* is difficult to transplant because the clump easily becomes disturbed in the process. For that reason, smaller, young clumps work best. But don't despair if those larger clumps collapse and turn brown. I have learned to trust the resilience of moss stems, and *Polytrichum* stems are a good example to support this trust. I transplanted one year after they had collapsed from their original orientation. They looked pretty bad when they went into the garden, and they didn't improve much. The next spring I was nearly ready to remove them, but didn't get the energy to do it. Then small green tips began to appear. Most of the sprawling clump still looks rather sad. They might have come back, but a chipmunk decided to occupy that part of the garden, building an entrance to its underground runway. Nevertheless, life is there, and perhaps with time the clump will fill in through stems.

Members of the genus *Polytrichum* can resist disturbance by the broom or bamboo rake used to remove fallen leaves and other debris (Ando 1987), and they are unusual among mosses for their resistance to drought and ability to withstand direct sunlight as well as shade (Steere 1968). *Polytrichum juniperinum* (Figure 8) and *P. piliferum* (Figure 26-Figure 27) do well if the clump integrity is maintained, again making small, young clumps easier to transplant.
As with *Sphagnum* (Figure 22-Figure 24), lime in some tap water can form crusts on the leaves (Fletcher 1991). One reason for this is that water for *Sphagnum* in nature must generally come from above. Although many mosses have good capillary action to move water externally, *Polytrichum* (Figure 25-Figure 27) species have large, waxy leaves that tend to repel water and do not move it well externally. Although they have one of the best developed internal conducting systems, they still take in most, if not all, of their water through the tip of the plant. Thus, water must be supplied from above and needs to be almost completely free from minerals. Even so, dust splashing from the soil can easily reach the leaves and contribute to their mineral accumulation.

Fletcher (1991) contends that the most easily grown mosses are those that have strong rhizoids, because they are least damaged by lime. For the remaining majority, one can use peat as a substrate, but that is often too moist. Another alternative is to use a sand substrate or in some cases organic soil free of lime, and water only with distilled water. Rain water is also a good choice, but may be contaminated with lime in areas with alkaline soil or limestone rocks. Nevertheless, as Fletcher points out, the impact of rainfall helps to wash off the minerals. A good spraying system is essential in areas where rainfall is infrequent. Fletcher advises to wash the mosses off with a spray of rainwater when they have accumulated minerals on their leaves.

Fletcher has succeeded in keeping *Polytrichum* (Figure 8) alive for 20 years, but he finds it necessary to transplant them every 1-2 years onto fresh peat. Once done, this permits old, dying shoots to produce new sprouts that emerge from the peat. On the other hand, I have had a bed of *Polytrichum juniperinum* (Figure 8) for seven years without disturbing it, and it is still doing well. It looks awful in the spring, but it recovers.

*Polytrichum commune* (Figure 25) and *P. strictum* (Figure 28) grow mostly in bogs and fens. *Polytrichum strictum* is aided in its quest for water by a white tomentum on the lower part of the stem. *Atrichum* (Figure 3) is a relative in the same family as *Polytrichum* (Figure 25-Figure 27). But its needs are somewhat different. Whereas *Polytrichum* has stiff, waxy leaves with lamellae across most of the surface, *Atrichum* has thin leaves (Figure 29) with lamellae only in the middle over the more narrow costa (Figure 30). This genus does best on soil, not peat (Fletcher 1991). Some species can be an invasive moss along paths (Figure 31) and can easily regrow from fragments. These provide a nice yellowish green.
When *Atrichum* dries, the leaves curl (Figure 32) and often turn brown (Figure 33). In this form it is not very attractive. It will look nice in a well-watered or humid garden.

Figure 32. *Atrichum altecristatum* drying and curling. Photo courtesy of Eric Schneider.

Figure 33. *Atrichum angustatum* with dry, brown leaves and capsules. Photo by Janice Glime.

**Leucobryum**

*Leucobryum glaucum* (Figure 34) was a favorite moss of many of my students. A common moss, it is easily recognizable by its whitish color and pincushion appearance. Its whiteness is emphasized in its name, with *bryum* meaning moss, *leuco* meaning white, and *glaucum* meaning whitish like wax. It goes by the common names of cushion, pincushion, or white moss. It likes acid soil, frequently occurring in conifer forests. Although it typically occurs in the shade, it can tolerate sun exposures. And the genus is common on many continents.

*Leucobryum* (Figure 34) is an acrocarpous moss, or upright type, producing stalks and capsules at the tips of the upright stems. Its mound form (Figure 34) makes a striking element in garden designs and borders, providing both a break in the topography and a striking contrast in color. This color contrast is due to hyaline cells that mask the green color of the leaves. As the moss dries, the hyaline cells lose water, the optics change, and the moss appears whiter.

Figure 34. *Leucobryum glaucum* at tree base, a common species in moss gardens. Photo by Janice Glime.

The texture of *Leucobryum* (Figure 34) cushions is somewhat coarse, due to the leaves that are more than one cell thick and relatively large. Cushion size can become quite large (Figure 35), and these will be very compact.

Figure 35. *Leucobryum glaucum* demonstrating the large cushions in an undisturbed forest in Copper Harbor, Michigan, USA. Photo by Janice Glime.

Annie Martin (Mountain Moss Newsletter winter 2010) relayed her experience relocating *Leucobryum glaucum* (Figure 34) from a gravel road where it was growing in full sun. It was dehydrated and white. She placed it among other *Leucobryum* plants in her garden and watered it three different times that evening. By morning it looked as fresh and alive as the established *Leucobryum* plants.

I have attempted cultivating *Leucobryum glaucum* (Figure 34) several times with only short-lived success. This moss seems especially susceptible to destruction by the leachates of leaf litter, even if the litter is cleared as soon as the snow melts.

Another habit of this plant might lead to dismay if one isn't familiar with its behavior. When it is reproducing
asexually, the leaves at the tip break off, providing a white covering of fragments on the colony (Martin 2010). This gives it a "cruddy" appearance for a while, but the plants are fine – just reproducing and dispersing. You can sweep these off with a soft brush to improve the appearance and at the same time disperse your Leucobryum (Figure 34) to additional locations in your garden.

If your Leucobryum glaucum (Figure 34) turns black, you do have a problem. This indicates that it is being kept too wet (Martin 2010). Perhaps this explains its sickly look in my garden when it emerged from the snow in spring. The slow melt in spring may have kept it too wet too long with little light and no opportunity to get dry. This discoloration can also be caused by fungal attack – an event further promoted by moisture. Martin advises to let the moss dry out for a while to see if it will recover.

On the other side of the coin, Leucobryum (Figure 34) has some remarkable recovery techniques. If it gets turned upside down, it will begin growing from the exposed side (Martin 2010), sometimes making a ball!

Martin (2010) finds this moss to be easy to pick up. The pincushion sits on the soil surface and grows on its own dead base (Figure 36). There is usually no soil attached. I have been advised to plant it on a bed of pine needles, but my one attempt at that was undone by a chipmunk that chose it for making the entrance to a burrow. It seems to like sandy soil and to avoid rich soil. As always, Martin warns us not to take bryophytes from parks or forests and to ask permission before collecting on private land.

Leucobryum bowringii (Figure 37), L. juniperoides (Figure 38) grow in mounds or cushions, creating a gentle, rolling landscape resembling miniature hills (like Figure 36). Leucobryum (Figure 39) is abundant and highly praised for its huge whitish cushions that provide beautiful contrast.

Dicranum

Dicranum is an acrocarpous genus that prefers shade. The most widespread and common species, Dicranum scoparium (Figure 40), forms cushions. The leaves curve and typically they all curve in one direction (Figure 41), creating the temptation to pet it. It provides a dark green contrast to Leucobryum (Figure 34) species and is found in

Figure 37. Leucobryum bowringii, a species used in Japanese moss gardens. Photo through Creative Commons.

Figure 38. Leucobryum juniperoides, a species used in Japanese moss gardens. Photo by Jan-Peter Frahm, with permission.

Figure 39. Leucobryum "spills" down the hill in a moss garden in Kyoto, Japan. Photo by Janice Glime.
many parts of the world, permitting its use in the moss gardens of Japan.

I have found this species as a well-developed moss among my flagstones on a path, where it was totally a volunteer.

**Thuidium delicatum**

*Thuidium delicatum* (Figure 43) is one of the fast-growing mosses (Martin 2010) and can take over a moss garden (Dale Sievert, pers. Comm. 13 October 2017). Despite the disturbances by chipmunks, I have found it to be persistent in my garden, showing up in new locations.

**Mniaceae**

*Mniaceae* can be similarly propagated, preferring damp, shaded places. *Plagiomnium cuspidatum* (Figure 42) has been quite successful in my garden and thrived as an invader among the shrubs around the campus library. Several members of *Mniaceae* are known and used for their big, lush leaves (Figure 42).

*Thuidium* is papillose (Figure 44), crunchy when dry (Figure 45), but soft when wet (Figure 43). It looks like a miniature fern and is often known as "fern moss." It will grow in open areas among grasses, but its need for some shade makes it a more likely candidate for shady portions of a garden.
**Pseudoscleropodium purum**

*Pseudoscleropodium purum* (Figure 46) is a large, pleurocarpous moss that tends to grow on acidic soil. It seems to like acidic grasslands, roadsides, and maintained lawns. It has attractive branches that look rope-like due to the concave leaves that end in a sudden, short, narrow tip. Like *Thuidium* (Figure 43), it is a rapidly growing species (Martin 2010). But be careful – it is also an invasive species, sometimes getting introduced when it is used as a packing material.

**Rhodobryum**

*Rhodobryum* (Figure 47) is a special genus that has very attractive individual plants. The leaves are crowded at the tips of the stems, making these look like a colony of miniature palm trees. The genus can grow in deep shade and seems to like it somewhat damp. Hilty (2017) describes its habitats in Illinois as moist ground in woodlands, wooded hillsides, ground at the base of trees in woods, swampy woodlands, shaded clay banks of ravines, moist decaying logs, limestone rocks along streams, moist limestone cliffs, shaded limestone ledges, limestone blocks in woods, thin soil over sandstone rocks in wooded areas, shaded ground in hanging fens, and sandy clay banks along creeks. Although it is a relatively uncommon moss, this presents a wide range of habitats where you can grow them.
Others

In the shade in Japan, common species include *Pyrrhobryum dozyanum* (Figure 50), and *Trachycystis microphylla* (Figure 51). Like *Leucobryum*, these latter taxa grow in mounds or cushions, creating a gentle, rolling landscape resembling miniature hills. *Hypnum* (Figure 52) and *Racomitrium* (Figure 53) are common in drier places and *Fissidens* (Figure 48) and *Atrichum* (Figure 3) in wet places (Steere 1968). Both *Hypnum plumaeforme* (Figure 54) and *Racomitrium canescens* (Figure 53) are able to grow without deep shade, but require frequent watering and weeding (Ueta & Deguchi 1980). In his webpage, Svenson (2000) recommended *Racomitrium canescens* as a moss for both sun and shade. It is quite drought tolerant, and it can form large, thick mats that have a broad tolerance, even to trampling. Other mosses suitable for gardens include *Eurhynchium praelongum* (Figure 55), *Rhynchostegium confertum* (Figure 56), *Brachythecium rutabulum* (Figure 57), and *Rhytidiales squarrosus* (Figure 2) (Fletcher 1991).

![Figure 50. *Pyrrhobryum dozyanum*, a large moss that does well in shady sites in Japanese gardens. Photo by Janice Glime.](image1)

![Figure 51. *Trachycystis microphylla* with capsules, a moss that does well in shady sites in Japanese gardens. Photo from Digital Museum, Hiroshima University, with permission.](image2)

![Figure 52. *Hypnum imponens*, a widespread species suitable for moss gardens. Photo by Janice Glime.](image3)

![Figure 53. *Racomitrium canescens*, a moss suitable for a sunny garden that might get dry frequently. Photo by Michael Lüth, with permission.](image4)

![Figure 54. *Hypnum plumaeforme*, an epiphyte in Japan. When planted in moss gardens, it requires frequent watering and weeding. Photo by Janice Glime.](image5)
Some mosses are especially adept at being transplanted and seem to survive despite drought or rainy season. Among these, I have been most successful with the medium-sized species of *Fissidens* such as *F. adianthoides* (Figure 48). It helps considerably if the shape of the original colony can be maintained, preventing exposure of longer stems by maintaining the shorter outer members of the cushion. This is especially true for cushion-formers like *Leucobryum* (Figure 39) and *Dicranum* (Figure 40). If this is not possible, pushing a rock against the exposed broken parts of the cushion helps to maintain the moisture there.

*Hylocomium splendens* (Figure 58) and *Pleurozium schreberi* (Figure 59) likewise do not transplant well. I have to wonder if a symbiotic fungus is involved. I was surprised that *Rhytiadelphus triquetrus* (Figure 60), a species in the same family as *Pleurozium* and *Hylocomium*, does well. *Thuidium delicatulum* (Figure 43-Figure 45) is somewhat successful, but mine was disturbed badly by a chipmunk that seemed to think that was the best place to enter its burrow. Followed by a very dry summer, *T. delicatulum* did not seem to be doing well. Nevertheless, it now occupies spots shaded by flowering plants and rocks, having dispersed there without my help.
Moss gardening is a growing industry, even in the United States and other parts of the world outside Japan. However, not all plants touted as mosses are truly mosses. Spanish moss (*Tillandsia usneoides*; Figure 61), a bromeliad, hence a flowering plant, is included among the types available from at least one moss seller. Rock mosses (*Selaginella*; Figure 62) and club mosses (Figure 63) (both Lycopodiaceae) are both cryptogamic tracheophytes, not bryophytes. Sheet moss, *Sphagnum* (Figure 20-Figure 24), and "bun" moss (growing in clumps) are other types listed and are true mosses. Sheet mosses include such mosses as *Hypnum* (Figure 52) and *Thuidium* (Figure 43-Figure 45) (Nelson & Carpenter 1965).

**Figure 61.** *Tillandsia usneoides*, Spanish moss, but not a real moss. Photo by George Shepherd, through Creative Commons.

**Figure 62.** *Selaginella rupestris*, a rock moss that resembles a moss when it lacks the strobili shown here. Photo by Nancy Leonard, with permission.

Annie Martin has *Climacium americanum* in her moss garden (Figure 64). This attractive moss looks like miniature trees. It is especially interesting when it produces capsules because it looks like a miniature Christmas tree with candles (Figure 66). This same moss grows in abundance along the path to the Frank Lloyd Wright house, Falling Waters, Pennsylvania, USA (Figure 65).

**Figure 63.** *Lycopodium annotinum*, a club moss, but not a true moss. Photo by Janice Glime.

**Figure 64.** *Climacium americanum* in MountainMoss Enterprises garden. Photo by Annie Martin <www.mountainmoss.com>, with permission.

**Figure 65.** *Climacium americanum* bordering the path at Falling Waters, Pennsylvania, USA. Photo by Janice Glime.
Sources

Few sellers are available for purchasing live mosses. And even where these sources are available, the mosses are usually expensive. Even when people have the sources and the money for purchase, gathering one's own is always a temptation. There are advantages to the latter – it shows the gatherer how and where the moss grows in nature and makes it easier to create the right microclimate for it.

BUT good stewardship is of paramount importance. And good stewardship precludes removing mosses from nature, whether it is a national forest or private land. Annie Martin, in response to criticism from Bryonetters, explained her method of developing moss mats for sale. She obtains her mosses in two ways – rescuing those that are about to be destroyed by development or because they are presumed to be a nuisance (roofs, parking lots, cracks in the sidewalk) or by obtaining permission from owners on private land. Judicious harvesting on private land can permit the mosses to grow back. On her own property, she cultivates these for sale. Martin expressed dismay that she could not get a permit to remove mosses in an area to be logged. Logging permits are permitted, but saving mosses beforehand is prohibited! They can't even be rescued to prevent destruction by trucks fighting fires. On the other hand, Martin has had good experience with private owners and business owners who give her permission to remove mosses. People in the area know her and call her before destroying unwanted mosses.

It also helps to know the relative growth rates of mosses. Annie Martin suggests that log mosses tend to fall in the faster growing category. I can add Plagiomnium cuspidatum (Figure 42), Fissidens adiantoides (Figure 48), and Marchantia polymorpha (Figure 16) as species that spread quickly.

Lawns

One typical push lawn mower running for one hour equals 43 new automobiles running for the same time (Martin 2010)! Go green with moss!

David Benner developed a moss lawn so he would never have to mow again (Dunn 2008). He hasn't watered or mowed his lawn since the Kennedy Administration, and it's doing just fine, reports Jancee Dunpee (2008) in her "In the Garden" column. Benner, a retired professor of horticulture, is a long-time moss lawn advocate. He is delighted that this approach is gaining momentum. But to visitors of his mossy lawn, he forbids high heels. (I wonder if it isn't more dangerous for the wearer than it is for the moss!)

Tim Currier, owner of Sticks and Stones Farm, Newtown, CT, USA, had been selling mosses for gardening for ten years, but in 2007 his sales increased by 30% (Dunn 2008). Celeste Kennedy, owner of Rolling Hill Farm in Green Bay, VA, USA, reports a 40% increase in the same time frame. Both homeowners and businesses have contributed to this rise in sales.

Dunn (2008) touts the advantages of mosses, including erosion prevention, density that repels weeds, no need for fertilizer, lack of herbivory by deer, and tolerates at least some trampling (e.g. Figure 67). It thrives in poor soil and only requires shade and occasional water.

The American Society of Landscape Architects predicted that native drought-resistant plants such as mosses would be a trendy change in 2008, providing a sustainable substitute for grass in lawns (Dunn 2008). Nancy Somerville, the executive vice president, states that the organization is seeing more creative plantings, with moss being "a great one." It satisfies needs for both better environmentalism and concerns about water. The EPA estimates that nearly one third of residential water use is for landscaping, a condition our diminishing water supply cannot sustain. The condition will only get worse with global warming, although in some areas more rain will fall.

Christine Cook, owner of Mossaics in Easton, CT, USA, contends that a moss lawn needs only one percent or less of the amount of water needed to maintain a suburban grass lawn (Dunn 2008). Benner's philosophy (Dunn 2008) is even better – he doesn't water; "things have to tough it out."
In 1962, when Benner first began his moss lawn, the only book he could find on the subject was written in Japanese (Dunn 2008). But he knew that moss thrives in acidic soil, whereas some people spread lime on a grassy lawn to eliminate moss. Therefore, he covered his lawn with a mix of sulfur powder and aluminum sulfate to acidify it. Three months later he removed the dead leaves, exposing the soil. Winter was the wait and see period, but in the spring mosses began to sprout everywhere. "It was like magic" he remembers. He didn't even have to plant – he just waited for spores to blow in. He now has 25 different kinds, and he didn't plant any of them! He has found fern moss (Thuidium sp.; Figure 43-Figure 45), hair cap moss (Polytrichum; Figure 8, Figure 25-Figure 28), rock cap moss (Dicranum; Figure 40), and cushion moss (Leucobryum; Figure 34, Figure 37-Figure 39) to be the easiest to grow. These four taxa are now sold by his son, Al Benner, through Moss Acres, a commercial establishment in the Poconos of Pennsylvania, USA. This business has actually increased about 30% each year, with such customers as the New York Times' headquarters for its atrium garden.

Benner senior claims that "some sort of magical invigorating energy goes through you when you stand on a thick patch of wet moss" (Dunn 2008).

It seems that moss enthusiasts are lurking everywhere. T. J. Turgeon, an executive vice president of a private bank for wealthy people, began his moss growing in 2004 (Dunn 2008). He says, "I'm having an absolute blast with it. I'm great at a dinner party, because I can talk about moss and no one's ever heard it before. People at work think I'm out of my mind. I don't know if other people do this, but wherever I go, I take moss."

Sallie Baldwin is a graphic designer from Greenwich, CT, USA, who has been turning her front yard into a moss lawn for 18 years (Dunn 2008). She sometimes amuses her neighbors by swapping a bit of "weedy" grass in her lawn for the "weedy" moss in theirs.

**Special Use Species**

You may choose to place some of your bryophytes in special locations that are more restrictive. These could include boulders, rock or concrete walls, or even paths. Some mosses are suitable for transplanting to these special situations.

If it is not too dry, Marchantia polymorpha (Figure 16) does well on disturbed soil. My Marchantia polymorpha (Figure 16) sported a bevy of children in a 25-cm circle around the parent plants, products of gemmae (Figure 68) splashed by the rain or the sprinkler system, and the parents had only been in the garden about three weeks! These young thalli were not only on the bare ground, but had become established on the cushions of Leucobryum (Figure 34) within reach.

![Marchantia polymorpha gemmae cups with gemmae. Photo by Dick Haaksma, with permission.](image)

Lawn Species

For substitute lawns and gardens, Eurhynchium praelongum (Figure 55), Calliergonella cuspidata (Figure 69), and Polytrichum juniperinum (Figure 8) serve well, although I doubt the North American populations of C. cuspidata would do so well in most terrestrial areas. In Europe this moss is found on dry hillsides, but in North America it behaves as an aquatic, at least anywhere I have seen it.

![Calliergonella cuspidata, a species that does well in lawns and gardens in Europe, but not in North America. Photo by Michael Becker through creative Commons.](image)

One of the most common lawn mosses is the pleurocarpous species Brachythecium rutabulum (Figure 57) (Fletcher 1991). It is among the largest of the Brachythecium species, has the typical plicate leaves, and can be distinguished from the others by its papillose seta (Figure 70-Figure 71). Its ability to grow in more sunny areas makes it also a good candidate for gardens as well as paths. It has invaded between the stones of the path along the side of my house. The moss Eurhynchium
**praelongum** (Figure 55) will grow in similar areas, but is a smaller plant.

Another lawn species in Europe is *Rhytidiadelphus squarrosus* (Figure 2). Well manicured and fertilized lawns are deprived of this species, but grassy meadows mowed by livestock may have it abundantly (Fletcher 1991).

Since mosses barely penetrate the soil with their rhizoids, only shallow soil of 1-2 cm is needed. Texture determines ability to attach but also determines moisture retention. Thus species that typically grow on sand are not likely to do well on humus or clay. Fletcher (1991) suggests bringing back a small plastic bag of soil that can be placed on top of a peat substrate. He contends that the soil type is more important for small moss plants than for large ones. Large plants most likely provide their own substrate after a few years of growth (Figure 72).

**Sun Species**

*Bryum argenteum* (Figure 73) and *Ceratodon purpureus* (Figure 12) are good sun species. *Bryum argenteum* changes little in appearance between wet and dry. It reproduces largely by fragmentation of the tips and typically does well in locations where there is a fair amount of foot traffic.

*Ceratodon purpureus* (Figure 12; Figure 74-Figure 84) is the moss my students nicknamed "tricky moss." It can take on many forms, depending on its microclimatic conditions. In spring, it is usually well hydrated and bright green (Figure 74-Figure 75). In summer, and often in autumn, it is usually dry and becomes crispy, brittle, and dark green or brownish (Figure 80-Figure 82). Its carpets can be somewhat loose (Figure 75) or quite tight (Figure 77). It is an early invader of roofs, areas on the ground receiving roof runoff, rock ledges, road sides, parking lots, and sparsely vegetated fields. In even grows in Antarctic pools (Figure 84). Nevertheless, it often does not respond well to transplantation.
Figure 74. *Ceratodon purpureus* in its fresh, green form. Photo by Michael Lüth, with permission.

Figure 75. *Ceratodon purpureus* with an uncommon loose form. Photo by Michael Lüth, with permission.

Figure 76. *Ceratodon purpureus*, with lush, green color after a wet summer and autumn. Setae are formed for next spring’s capsules. Photo by Janice Glime.

Figure 77. *Ceratodon purpureus* with red setae and young capsules. Photo by Annie Martin <www.mountainmoss.com>, with permission.

Figure 78. *Ceratodon purpureus* in moss garden at Mountain Moss Enterprises, showing spring growth and mature capsules. Photo by Annie Martin <www.mountainmoss.com>, with permission.

Figure 79. *Ceratodon purpureus* showing dry portion (upper left) and moist portion. Photo by Janice Glime.
Figure 80. *Ceratodon purpureus* showing dry plants in autumn. Photo by Janice Glime.

Figure 81. *Ceratodon purpureus* dry with immature capsules. Photo by Bob Klips, with permission.

Figure 82. *Ceratodon purpureus* in brown state after a dry summer. Photo by Janice Glime.

Figure 83. *Ceratodon purpureus* with mature capsules and dry leaves. Photo by Michael Lüth, with permission.

Figure 84. *Ceratodon purpureus* submersed with air bubbles at Casey Station, Antarctica. Photo courtesy of Rod Seppelt.

**Wall Species**

The common European moss *Tortula muralis* (Figure 85) easily establishes itself on cement, bricks, or other walls (Fletcher 1991). Although it may be found on soil, this is not its best habitat. For rooftops (the clay tile kind), concrete, and rock walls, Svenson (2000) recommends *Tortula muralis* and *Didymodon vinealis* (Figure 7).

Figure 85. The moss *Tortula muralis* is often found on rooftops, concrete, and rock walls; *muralis* means "of the wall." Photo by Michael Lüth, with permission.
Path Species

The most famous of the species growing on paths is *Bryum argenteum* (Figure 73), silver moss. It is easily dispersed by its deciduous tips whenever something walks across it. Hence, it is common in cemeteries and other soil areas with light foot traffic.

In addition to the ubiquitous silver moss, *Barbula* [ *B. unguiculata* (Figure 86), *B. convoluta* (Figure 87), *B. cylindrica* (Figure 88), and *B. fallax* (Figure 89)] is common, especially between bricks or stones (Figure 90) (Fletcher 1991). Species of *Barbula* add a fresh green color to the garden (Figure 91).
Based on invasion of a newly cut ski trail, I would recommend *Atrichum alcestratum* (Figure 92). This moss invaded quickly about 10 years ago and is still present today. The plants provide a yellow-green color when fresh. However, when they dry out they are not nice to look out. If a watering system is present, they will benefit.

Figure 92. *Atrichum alcestratum* drying, a species tolerant of living on paths. Photo courtesy of Eric Schneider.

Annie Martin includes *Ceratodon purpureus* (Figure 93-Figure 94) among her plantings between stones of paths. If you are willing to wait, this species will probably arrive by itself.

Figure 93. Stone path planting, showing Annie Martin pushing mosses, including *Ceratodon purpureus*, into cracks between the stones. Photo courtesy of Annie Martin <www.mountainmoss.com>.

Figure 94. *Ceratodon purpureus* with capsules in stone path in March 2017. These were planted here in December 2016. Photo courtesy of Annie Martin <www.mountainmoss.com>.

I was surprised to find *Hedwigia ciliata* (Figure 95) covering paths in our local cemetery (Figure 96). The paths were covered in gravel and could be identified by the yellow-green color of the wet moss. The moss all but disappeared from a distance when it dried and became whitened. I would not ordinarily think of this as a path moss, but it was certainly doing well in parts of the cemetery.

Figure 95. *Hedwigia ciliata* drying, a moss that grows on pebbles and rocks. Photo by Janice Glime.

Figure 96. *Hedwigia ciliata* wet, on pebbles, in the Houghton cemetery path. Photo by Janice Glime.

Erosion Control

The use of mosses to control erosion has probably been known for many centuries. Shana Gross (Bryonet 23 January 2009) reported her experiments on establishing moss growths for this purpose. She examined effects of fragment size, substrate, fragment location along the shoot, watering methods, hormone application, and nutrient application on *Bryum argenteum* (Figure 73), *Ceratodon purpureus* (Figure 12; Figure 74-Figure 84), and *Polytrichum juniperinum* (Figure 8). The responses depended on the species. She strongly supports the use of mosses for erosion control, but this adventure is not without its problems. The mosses grew well in the greenhouse, but responded poorly in the field. Fragments planted in the field required some means to affix them until
they became established. Transplanting clumps from field populations was more successful, but that is not feasible for larger areas. She suggested using methodology from cryptogamic crusts (see Belnap 1993), where inoculum of the species improved colonization over letting nature do the propagating.

Shaw (1986) developed experimental propagation methods. He was successful in propagation when he dried the gametophytes (leafy plants), ground them into a fine powder, and sowed them on native soil. His purpose was to develop a laboratory protocol for evolutionary studies, but it could be applied to getting starter biomass for stopping erosion. He found that the plants presented normal morphology.

Cultivation

Fletcher (1991) has found that mosses can be grown in a variety of containers, including Perspex sandwich boxes, Tupperware, plastic ice cream boxes, glass jars, and aquaria. However, bryophytes kept in this way typically do not survive for more than a few months. He replaced this method with a seed tray, covered with a sheet of glass or sheet of acrylic plastic. These must be kept in cool, open air and shaded. But even this improved method does not work as one might hope; bryophytes fare well for only a few weeks to months. Fletcher even tried peat beds or other means to maintain moisture, but this made matters worse. Clearly there was a need for a better method.

Johannes Enroth related to Bryonet (5 March 2010) his experience growing *Racomitrium canescens* (Figure 53) experimentally in a cemetery. The study group took advantage of the fragmentation growth capabilities of mosses and cut the shoots into small pieces (see also Figure 97). They spread these on sand and kept them moist until they became established. "The moss grew fast and formed a dense, beautiful cover that changed color along with changing air moisture" (Figure 105). This moss is a good suggestion for sunny areas.

In Australia, Alison Downing (Bryonet 23 January 2009) and her coworkers experimented with calcareous and acid soils to look for the success of dormant propagules. They collected soil in the field and carried it back to the lab in cotton bags to prevent mold in the humidity of plastic bags. They collected only the top 10 mm of soil, avoiding the collection of plants. In the lab, they sieved the soil in a clean environment. The sand foundation was steam-sterilized to avoid contamination from the sand. Dry heat is not effective for the resistant bryophytes unless it is at extremely high temperatures. Using the sterilized sand, they filled a 10-cm-diameter plastic horticultural pot to about 1 cm below the top. The collected soil was placed in a 5 mm layer on top of the sand. The soil propagules were cultured in a greenhouse, watered carefully with demineralized water, and the pots covered with sheets of glass to prevent contamination. The pots were checked daily and kept moist by misting with demineralized water when needed. After 8 weeks the calcareous and arid soils exhibited 100% bryophyte cover. The propagules in the non-calcareous soil required a few more weeks. Even rare species can show up using this method.

Annie Martin (Bryonet 6 August 2010) prepares the ground to prevent the invasion of rooted plants. She has used five different substrates (Figure 98-Figure 99) in her gardens, including 0.3 cm synthetic felt, 0.6 cm felt with adhesive plastic backing (used for installing carpets), basic landscape fabric (paper thin), black landscape fabric 0.5 cm thick (perforated and similar to felt; Figure 98), and coco fiber mat (to control erosion; Figure 98-Figure 99). For *Bryum* (Figure 73), *Ceratodon* (Figure 12; Figure 74-Figure 84), and *Hedwigia* (Figure 95), she uses asphalt shingles for a substrate.
These substrates are not eco-friendly or natural. When installing a moss garden for her clients, Martin (Bryonet 6 August 2010) plants the mosses directly on the ground. In the nursery, the felt substrates help in retaining moisture and make it easier to lift the mosses into flats or boxes for shipping.

As Annie Martin (Bryonet 8 March 2012) gained experience, experimenting with various substrates, she developed a preference for Geo-Tex fabric as the primary substrate for field production. This retains moisture and provides a weed barrier. Martin (Bryonet 8 March 2012) plants large areas by transplanting hand-sized colonies and spreading fragments in between (Figure 100). Watering for the next few weeks is critical, but make it gentle.

Figure 100. Planting of bryophytes on mat of coco fibers. Annie Martin disperses fragments between the clumps. Photo by Annie Martin <www.mountainmoss.com>, with permission.

Katherine Frego (pers. comm. to Nancy Church 6 April 2010) reported on her success in growing *Pleurozium schreberi* (Figure 59), *Dicranum polysetum* (Figure 101), *D. scoparium* (Figure 40), *Ptilium crista-castrensis* (Figure 102), and *Ptilidium ciliare* (Figure 103). She found she could collect them at any time. She then dried them in the shade and chopped them with scissors. These fragments were stored in paper bags for months. When she was ready to culture them, she put them on a humus-y soil and covered them with a hairnet to keep them in place. She sprayed them thoroughly to wet them and they sprouted new shoots very soon afterwards. Fragments about 1 cm long formed new shoots directly. Smaller shoots formed protonemata first, and these were more fragile and vulnerable.

Figure 101. *Dicranum polysetum* with capsules, a moss successfully grown from dry fragments. Photo by Janice Glime.

Figure 102. *Ptilium crista-castrensis*, a moss successfully grown from dry fragments. Photo by Janice Glime.

Figure 103. *Ptilidium ciliare*, a moss successfully grown from dry fragments. Photo courtesy of Eric Schneider.

Johannes Enroth (Bryonet 6 August 2010) became the curator of a stone and moss garden in the courtyard of the Ministry of Education in downtown Helsinki, Finland. The original garden, planted by Timo Koponen in the 1980's, had only three species: *Racomitrium canescens* (Figure 104-Figure 105), *Plagiommium cuspidatum* (Figure 42), and *Cladonia dendroides* (Figure 106). In 2007, the number of species had expanded to 15, dominated by *Encalypta streptocarpa* (Figure 107). The latter forms a pure mat of several square meters on the sand in the middle of the yard.

Figure 104. *Racomitrium canescens* exhibiting dry appearance. The tips look frosted and add interesting contrast to other shades of green in the garden. Photo by Michael Lüth, with permission.
I have experimented in my own garden, using various substrates and cultivation methods. One of my early attempts was to use burlap (Figure 108-Figure 109), placing it on top of visqueen plastic to prevent seeds in the soil from germinating and penetrating into the moss carpet (Figure 109). It also meant that seeds germinating on top would be unable to drive their roots into soil. Netting over the mosses helped to hold them in place when chipmunks and squirrels ran over them (Figure 110). But apparently the soil helps in the retention of moisture because these mosses dried out more quickly than those directly on soil.

Next I tried cutting the bryophytes into fragments (Figure 111) and spreading them on brown felt (Figure
112-Figure 113). This met with similar problems. The felt dried quickly, became stiff, and the moss fragments likewise dried out.

To understand the best way to keep bryophytes, we must understand how they normally grow. Rather than being the moisture-loving plants portrayed in most popular literature, they actually prefer places with good air circulation and only a small percentage of species grow in the damp, enclosed places most people think of. Rather, many taxa grow on dry rocks, sand, or in open sun. Some prefer acid rocks and some prefer limestone. Most cannot grow where leaf litter will cover them in the fall and remain there for the winter. Some do well in pine forests where they can grow over or between the needle litter.

Johannes Enroth, Bryonet 9 March 2010, recalls covering a surface with *Racomitrium canescens* (Figure 104-Figure 105) shoot fragments. Within a matter of months, the moss formed a "nice mat." Two *Polytrichum* (Figure 8 , Figure 25-Figure 28 ) species from spores and individual shoots planted in the soil were not very successful. Growth was slow and the planted shoots often died. *Plagiomnium* sp. (Figure 42) was more successful.

Nancy Church (pers. comm. 27 July 2010), formerly from Moss Acres, told me that they used a product called Terra Blend70/30 with Ultra Grow. The 70/30 ratio refers to the wood fiber/paper fiber content. The Moss Acre folks believe the "Ultra Grow," the ingredients of which are kept a close secret of the manufacturer, is part of what makes this so effective with mosses. Keith Bowman, one of Dr. Kimmerer's graduate students, worked with Moss Acres on experiments with the Ultra Grow cellulose, and Church was curious to see if the fertilizer helped the vascular plants (weeds) or the moss more. It has certainly helped the moss in all of the "amateur" experiments they've done at Moss Acres.

Sandrine Hogue-Hugron (Bryonet 31 May 2011) experimented with growing bryophytes to restore sand pits. Although there was colonization on the bare sand, colonization was optimal when the sand was mixed with peat. Peat is also a good substrate for making a bog garden. Industrial peat is a good choice because it is usually free of propagules. The peat can be further sterilized by heating to 60ºC for an hour and a half.

**Winter Culture**

Martin (2010) finds that winter is a good time to harvest and plant mosses in western North Carolina, USA. But if you live in the Keweenaw Peninsula of Michigan, USA, the mosses are under a meter or more of snow. In Japan, the best time to plant is just before the rainy season, reducing the need for frequent watering. Martin reports that her mosses emerge from short snowfall events looking green, whereas when mine emerge after 4-5 months of snow burial, they often look brown, becoming green when new growth appears.

Freezing doesn't harm the mosses (Figure 114), with some photosynthesizing at temperatures below 0ºC (Liu *et al*. 2001). Snow insulates them, and I am guessing that some photosynthesis is able to occur in the light filtering through shallow snow in spring and fall. Martin (2010) has been successful in planting mosses on frozen ground, but the moss itself should be thawed first. She warns that on warmer days when the temperatures are above freezing, the garden should be watered, especially during the first few weeks after planting. (And don't forget to empty the hose so it won't freeze and burst.)
When there is no snow cover, winter is a season of growth, along with spring and autumn when the air is cool. Bryophytes tend to be dormant in the heat of summer, especially if they are dry.

**Moss Plantations**

When visiting a commercial moss plantation in Japan near Nagoya, I found the ground planted in several species of *Polytrichum* (Figure 8, Figure 25-Figure 28) and its relatives *Pogonatum* (Figure 115) and *Atrichum* (Figure 3, Figure 92). The landscape was dotted with small pine and fig trees, providing light shade for the mosses beneath (Figure 116). Other growers cover the mosses with straw or bamboo screens to provide shade. The proprietor proceeded to show me, with hand motions and occasional translations by N. Takaki (for whom *Takakia* is named), how the mosses were dried, then pulverized between the hands, and sown like grass seed in wooden flats. These flats were kept well watered in full shade until the mosses were well established. Then they were transplanted outside under the shade of the pines and figs until they formed a carpet (Figure 116).

When they were harvested for a buyer, they were removed in squares about 20x20 cm and stacked to dry (Figure 117). Their new owner would then plant them, checkerboard fashion, in a dooryard garden or along a small backyard path, trampling them into the ground and once again breaking off small fragments of moss. A small board can be used to press and spread the mosses instead of trampling, but pressing them into the ground is important. It is the ability of mosses to regenerate from fragments that makes this process work so well. The fragments and new growth eventually fill in the empty squares of the checkerboard, providing a continuous carpet for the moss garden, although Schenk (1997) advises us that it can take 2-3 years for a *Polytrichum* (Figure 8, Figure 25-Figure 28) carpet to fill the gap. Mosses such as *Brachythecium* (Figure 57), with their horizontal growth form, may fill the gap within a year.

This ancient art of planting mosses by pulverizing them has been adopted by the American Horticulturist Society. In their Fact Sheet for Moss Gardening, they recommend grinding dried moss and spreading it as powder, cautioning the gardener never to buy moss from a grower unless you are certain that the moss has been propagated by the seller and not taken from the wild—good conservation advice.

Experimental studies support this pulverizing method as well. Miles and Longton (1990) found that fragmentation was superior to spores in the development of upright shoots in such common garden mosses as *Atrichum*...
undulatum (Figure 3) and Bryum argenteum (Figure 73).
In fact, Shaw (1986) contends that whether in an industrial setting or in the laboratory, starting cultures from spores is impractical for many species. He found, using the pulverizing method, that within a month, new gametophores were evident in most species, and within three months regenerated plants filled his pots. He had the best results when the plants were misted for six seconds every thirty minutes. Svenson (2000), on his moss gardening website, recommended filling in the bare spots between patches of moss by using the pulverizing method. This can be done by putting pieces of moss in a blender with a small quantity of water for two minutes, then spreading them between the transplanted mosses.
A mixture of 50% coarse sand, 30% vermiculite, and 20% peat provides a good substrate, and the optimum growth temperature for temperate zone mosses is believed to be around 10°C (Iwatsuki 1979). In the laboratory, Petri plates with layers of filter paper saturated in tap water have been successfully used to regenerate Atrichum undulatum (Figure 3) leaf fragments (Gemmell 1953); in nature, the soil will do just fine if kept moist. [Note that not all tap water is created equal; it may kill some species and be worse in some areas.]
My students at Michigan Technological University successfully grew protonemata from fragments of five North American taxa in genera commonly used in moss gardens [Atrichum oerstedianum (Figure 118), Dicranum scoparium (Figure 40), Fissidens adiantoides (Figure 48), Leucobryum glaucum (Figure 34), Plagiomnium affine (Figure 119)] in a dish garden, using this method and a modified version with a strip of cheesecloth over the fragments to retain moisture (Plante et al. unpublished data 1993; pers. obs.). Protonemata developed in 2-3 weeks. Fragments placed on sand alone failed to produce any growth during the experiment. In addition to the fragments, whole plants were planted, and at least a few plants of Atrichum oerstedianum, Fissidens adiantoides, and Plagiomnium affine produced new branches, although the original branches became brown and wilted. Subdued light (900 lux for 8 hr d−1) and moderate temperatures (ca. 20°C) seemed more favorable than a higher light intensity and temperatures of 38°C.

It is during the critical early establishment stage that moisture is very important, and the Japanese often time their planting to coincide with the rainy season so that the mosses get natural watering daily. Yet, the entire first year and often the second require careful attention to water requirements. As discussed in the chapter on "Water Relations: Rehydration and Repair," frequent wetting and drying is quite detrimental to a moss because each time it is dried and rewet it must repair damaged membranes, often requiring a full day before there is any net energy gain. Transplanting brings with it its own share of damage and adjustment that makes the mosses less tolerant of natural stresses.
It is interesting that Schenk (1997), with his long-time experience as a moss gardener, reports that few mosses will grow successfully from fragments. He touts Leucobryum (Figure 34; Figure 120-121), Racotytrium (Figure 53), and Dicranoweisia (Figure 122) with this ability, but finds others to be reticent to yield to the gardener's wishes. Nevertheless, as he acknowledges, all mosses share this ability to regenerate from fragments, and I have observed in nature young shoots of Scapania undulata (Figure 123) (Glime 1970) and Atrichum (Figure 3, Figure 92) (Glime 1982) developing from leaf fragments to which they were still attached. Fissidens (Figure 48) species are especially adept at this, and I soon found new colonies all over my garden room, presumably transported about as fragments by my box turtle – they had never produced any capsules. In the lab, Plante et al. (unpub. data 1993) were successful with both whole plants and fragments of Fissidens.
One of the most luxurious growths of moss I have seen outside of nature was on a discarded piece of carpet that was able to soak up and maintain moisture over long periods of time (see, for example, Figure 124). This is reminiscent of the technique of using cheesecloth on flats to grow mosses that are to be draped over rocks or uneven landscapes. The cheesecloth method takes advantage of fragments, although spores can be used as well (McDowell 1968). Partially dried moss fragments must be spread over cheesecloth that overlies a sand-peat moss or sawdust mix in a flat. The pH can be lowered by soaking the mix in a solution of 1 part skim milk or prepared powdered milk to 7 parts water (McDowell 1972). These are covered with a second piece of cheesecloth and kept moist by misting.

When the plants are well established (about 4 1/2 months), it is easy to transplant them by lifting the soil/cheesecloth layer. The cheesecloth can be cut to shape as needed. Some gardeners have been successful in growing rock-dwelling taxa this way as well. The cheesecloth can easily be draped over rocks. The mosses grow through the cheesecloth, and eventually the cloth will rot away. If the white color of the cheesecloth is bothersome, coffee (soak in 3 teaspoons instant coffee per cup boiling water for 10 minutes) can be used to stain the cloth (McDowell 1972). Crum (1973) has found that *Brachythecium salebrosum* (Figure 125) and *Plagiomnium cuspidatum* (Figure 42) are relatively easy to grow in this way, emphasizing that regeneration works better than transplantation.

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Figure 121. *Leucobryum* sp. showing protonemata growing from leaf fragments. Photo courtesy of Andi Cairns.

Figure 122. *Dicranoweisia crispula*, a moss that is easily grown from fragments. Photo by Michael Lüth, with permission.

Figure 123. *Scapania undulata*, a leafy liverwort species that regenerates from leaf fragments. Photo by David T. Holyoak, with permission.

Figure 124. This rug has a luxurious growth of *Ceratodon purpureus*. Photo by Michael Lüth, with permission.

Figure 125. *Brachythecium salebrosum* with capsules, a moss that will develop well on cheesecloth. Photo by Michael Lüth, with permission.
Even when mosses are transplanted or sewn directly on the garden soil, it is often necessary to spread a cover of cheesecloth to prevent damage from birds that would destroy the tender plants before they could gain sufficient establishment. If the moss is to be transplanted, the cheesecloth serves the double purpose of keeping the moss from breaking apart as it is handled.

Planting on rocks can be a challenge, as the moss may buckle up on the dry substrate, or simply get blown away. One solution to this is to glue them there with a good epoxy such as Araldite, a very strong two component epoxy resin (Paul King, pers. comm.).

**Transplanting**

For those preferring the transplant method, the best place to gather moss is rich woodland areas (Pullar 1966/1967) and the best time of year to collect is from autumn into the winter months (Iwatsuki 1979), depending on where you live. But mosses should not be gathered without permission of the owner, and on public lands a collecting permit is usually required (and should only be done if the area is scheduled for destruction). Furthermore, bryophytes should not be imported from other countries for one's personal gardens, and when such importation is necessary for an institution, proper permission must be gained from both the country of origin and the one of import.

Mosses can be transported in a variety of ways fitting your own convenience. Annie Martin uses plastic sleds (Figure 126) and plastic flats (Figure 127). Paul More uses cardboard boxes (Figure 128). I have used deeper boxes, putting layers of newspaper between the layers of mosses to separate them. The newspaper can be omitted, but it is easier to separate the mosses later when the layers are distinct. I have also used ice cream buckets on short excursions when I had no transportation (Figure 129).
Although bryophytes lack roots, their rhizoids are often connected to symbiotic fungi (e.g. Davey & Currah 2006; Renzaglia et al. 2007; Pressel et al. 2010). Therefore, they should not simply be plucked from their substrate. It is preferable to bring the top layer of soil with them. This is important for several reasons. It will help to maintain fungal connections and provide an inoculum for new associations to establish; it will help hold cushion growth forms together; and it will retain the suitable nutrient and pH conditions of its original substrate, at least initially.

For some species, removal from their forest habitat might mean removal from a necessary host plant. Some bryophytes, in particular Cryptothallus mirabilis (Figure 130), require a photosynthetic partner to provide carbohydrates. This partnership can be mediated by the mycelial threads of a fungus that is also linked to a shrub or tree that reaches closer to the canopy. Or it might be linked to decaying leaves or logs. This is a recent area of research, so we know little about these partnerships, but they may explain the failure of some transplants.

Pinning the bryophytes to the substrate with wooden toothpicks angled through the mat (Figure 131), a technique I learned from Jon Shaw, helps to maintain contact with the substrate during dry periods, and of course keeps them where you put them. Special moss clips (Figure 132) are available for anchoring the mosses, but toothpicks work and are less conspicuous.

In this regard, Schenk (1997) advises maintaining as much soil depth as possible when gathering the clump of moss, whereas Bland (1971) advises one to remove as much as possible to prevent curling up at the edges (Figure 133), turning the moss upside down and washing away the soil to prevent shrinkage. I recommend the former because it causes the least disruption of rhizoids and one doesn't have to worry about destroying possible mycorrhizal connections, which may be more common than we realize. It does require keeping the moss and soil wet until the soil has blended with the underlying substrate.

Signs of death occur rapidly in transplants, but those clumps that remain green will become stabilized within a few weeks. Once they do, Ando (1971) suggests that regular watering can be discontinued. Seike et al. (1980), on the other hand, recommend daily watering.
Maintenance of the integrity of the clump is of utmost importance. If it is necessary to expose the lower part of the stems around the edge of the clump (Figure 134) due to using only part of a clump or other disruption, these lower parts should be protected either by building up soil around them or pressing a rock next to them (Figure 135). If some of the stems are taller than the other stems, they can be cut to avoid having them dry out. For many bryophytes, a new branch will form and continue growing.

![Figure 134. Bryum sp. with exposed edge in the forefront. The moss will dry out here and die back from the edge. Rocks placed against such edges, or other moss clumps, will reduce the drying, but frequent watering after transplanting is important. Photo by Janice Glime.](image)

If you are trying to establish a lawn, you might be able to purchase a ready-to-go mat (Figure 136). These can be rolled up much as the sod purchased for grass lawns. With a landscaping mat under them, they are easy to handle (Figure 137) and to cut to fit any area (Figure 138-Figure 140).

![Figure 136. Pre-vegetated mat from MountainMoss. Photo courtesy of Annie Martin <www.mountainmoss.com>.](image)

Weeding of the imported moss is important so that competition is not planted with the mosses. Leaf, stick, and seed litter should be removed, but caution must be used to prevent disruption of the clump.

Some gardeners recommend making a depression, laying a bed of gravel, then putting the mosses on top, but still within the depression. Exposure of the lower parts of the moss seems to be a prescription for disaster due to excessive drying.
Figure 139. Removing cut portion from the moss sheet. Photo courtesy of Annie Martin <www.mountainmoss.com>.

Figure 140. Moss mat after it has been positioned and cut to allow for planting flowers. Photo courtesy of Annie Martin <www.mountainmoss.com>.

It is to our benefit in gardening that the mosses respond quickly to the stresses of sun, showing bleaching or browning of leaves in only a day (Schenk 1997). This quick forewarning tells us to try a different location, a different moss, or provide more care and maintenance.

Substrate Conditioning

Successful moss gardening requires at least a modicum of knowledge of the ecology of mosses, and a student of their ecology has much to learn from the successful moss gardener. Aside from the expectation that they will require a moist, shaded habitat, most non-bryologists have little understanding of bryophyte requirements. Most mosses seem to prefer a pH of about 5.5, attainable by spreading powdered sulfur over the soil (about 1.1 kg per 9 m²) (Schenk 1997). Alternatives include powdered skimmed milk, aluminum sulfate, or rhododendron fertilizer. A light misting from the sprinkler will help to affix these to the ground. However, Alison Downing reminded us on Bryonet (20 April 2005) to be careful using milk (or any lime) on sandstone because the calcium in milk can completely change the nature of a sandstone habitat. Instead of Campylopus (Figure 141), Lophocolea (Figure 9), Sclerodontium (Figure 142), and other typical sandstone taxa, you will find instead introduced or cosmopolitan taxa such as Funaria (Figure 143) or Bryum (Figure 73).

Figure 141. *Campylopus introflexus*, an invasive species that will be discouraged by milk applied to sandstone due to the calcium. Photo by Michael Lüth, with permission.

Figure 142. *Sclerodontium pallidum*, a species that will be discouraged by milk applied to sandstone due to the calcium. Photo by Niels Klazenga, with permission.

Figure 143. *Funaria hygrometrica*, a species tolerant of charcoal and calcium. Photo by Michael Lüth, with permission.

Maintenance

Martin (2016) advises using the three W's in caring for a moss garden: Water, Walk, Weed. Although mosses will survive extended drought, they won't look nice. And when you are first propagating them, whether by spores, fragments, or transplants, they need constant hydration, often requiring watering. Walking on more mature plants helps to spread them through fragmentation (Figure 144). Weeding needs no explanation — the tracheophytes can quickly outgrow them.
No Fertilizers?

Fertilizers must be applied to mosses with great caution. An "elixir" of manure seems to be a suitable supplement (Schenk 1997). Svenson's (2000) website suggested steeping cow manure in a burlap or cheesecloth bag in a bucket of water for 3 weeks (outside, I hope!) before applying it. An alternative is using 1 part of skim milk or buttermilk to 7 parts of water and applying twice per day for two weeks in spring to acidify the soil. Most other fertilizers, especially if applied dry, can kill the moss. David H. Wagner (Bryonet 8 May 1998) told us that the egg albumen mixed with buttermilk would polymerize and act as a protein binder, creating an adhesive. As the mosses grow and become established, the mix becomes a source of nitrogen for them.

Iwatsuki and Kodama (1961) caution that fertilizer should never be used for mosses. Contrasting to the powdered sulfur acidifier recommendation of Schenk (1997), Stubbs (1973) recommends the use of fertilizer based on iron sulfate as a means of killing moss fast. In fact, fertilizer is a commonly suggested means for getting rid of unwanted mosses. On these one-cell-thick leaves, the dry powder soon goes into solution when water becomes available, greatly altering the osmotic relationship between outside and in and introducing the potential of membrane damage. Furthermore, dry fertilizers tend to be hygroscopic and draw water from the delicate and unprotected moss leaves. The effect is much like the desiccation seen among the mosses on Mount Rainier shortly after the eruption of nearby Mt. St. Helen's (Figure 145). However, if applied in liquid form followed by frequent watering, fertilizer can benefit the moss. Lime fertilizers, however, should be avoided due to their alteration of the pH. The seeming contradiction to the advice of Schenk is that he suggests applying the acidifiers to the soil and wetting them down before the moss is planted there.

Horticultural magazines and texts extol the advantages of a wide variety of human foods as starters for mosses. Gillis (1991) describes making moss beds by mixing a handful of moss, a can of beer, and a half teaspoon of sugar in a blender, then spreading the mix 5 mm thick on the ground. She found that the mosses grew within five weeks. In addition to beer, egg whites, and buttermilk, others have successfully used rice water, carrot water, potato water, and just water as the medium. Ellis (1992) claims that such mixtures, even the water, are particularly helpful in adhering the moss fragments to rocks. My own experience is that these food additions serve best to feed fungi and pillbugs, thus being detrimental to the mosses.

Watering

The subject of watering is an interesting one. Some people are adamant that only distilled, demineralized, or rainwater can be used. Others have no problem using tap water (Figure 146). This argument does not surprise me. Tap water can differ greatly between locations. I was amazed to find Fontinalis (Figure 147) growing happily for years in a tap water aquarium in Japan. But when I tried to grow several species in tap water in New Hampshire, USA, the copper in the water from the pipes turned the plants yellow overnight. After that failure, we used only stream water.
Figure 146. Sprinkling system used by Paul Moore on his moss lawn. Photo courtesy of J. Paul Moore.

Figure 147. *Fontinalis antipyretica*, an aquatic moss that is sensitive to heat. Photo by Bernd Haynold, through Wikimedia Commons.

City water is much more likely to kill bryophytes than spring water. City water usually has chlorine added and suffers from the solution of metals from water pipes. It also matters if the tap water is the exclusive source of water. Minerals can accumulate on the surface on the bryophytes; intermittent rainfall can remove some of that accumulation. pH can make a difference because it is less likely to carry calcium that forms crusts on the mosses. Annie Martin (Bryonet 22 June 2013) has had no problems using tap water (Figure 148) for at least 10 years, but her water is acidic. Martin considers adequate watering to be the most important factor in moss garden success.

For my own garden, I used collected distilled water or rainwater for several years (Figure 149). Other years I used only misting with a sprinkling system that used tap water (Figure 150). However, that tap water went through a filtering system that removed some of the minerals, and spraying it in the air helped to dissipate the chlorine.

Figure 148. Furman-Moss-Watering at Mountain Moss. Photo courtesy of Annie Martin <www.mountainmoss.com>.

Figure 149. Distilled water and collected rainwater are both good sources of water if your tap water is detrimental to your bryophyte garden. Since the garden is outdoors, the bryophytes collect dust and get their nutrients from that dust when they are watered. Photo by Janice Glime.

Figure 150. Sprinkler in my own moss garden. When the water comes on, the sprinkler head rises to about 15 cm and sends water in all direction.

One gardener in Raleigh, NC, USA, has been very successful growing *Mniaceae*, including *Plagiomnium* (Figure 42) (reported by Annie Martin, Bryonet 6 August...
reduce weed invasion. Watering in unplanted areas also resulted in a carpet of thriving Plagiomnium that arrived by itself.

Ann H. Martin (Bryonet 6 August 2010) warns that not all mosses have the same nutrient or watering requirements. She finds that Bryum species (Figure 73) need to dry out sometimes; likewise, Dicranum scoparium (Figure 40) will not tolerate being wet all the time. I have never tested it because my own garden is too small to replicate, but I have assumed that watering the mosses on a sunny, hot afternoon is not wise. They can't close guard cells like flowering plants, and they are C3 plants that respire more than they photosynthesize at higher temperatures, often starting above 20ºC. I have assumed that it is best to let them shut down on hot, sunny afternoons. I do know that Fontinalis species (Figure 147) cannot sustain vitality if kept in water at 20ºC for more than 3 weeks (Glimé 1987), presumably due to the high respiratory ratio. In my own moss garden, I have an automatic sprinkling system that comes on at 6 am, giving the plants sufficient moisture to photosynthesize in the cool hours of the morning. This regime seemed to work well. In hotter locations, an earlier watering time might be preferable.

One dealer recommends daily misting as opposed to intermittent watering to avoid drying or water logging. But one must exercise caution here. Bryophytes that suffer frequent wetting and drying (to the point of damage) will not have sufficient time for repair during the intermittent moist periods. Consider a sprinkling system to keep things moist, preferably on a timer to water at night, permitting the bryophytes to photosynthesize in the cool morning.

I have found that advice I get on moss gardening from another part of the country often does not work for me, and I end up going back to my original methods. Alkaline soils or clay soils will require different watering regimes from those of humus, and ease of transplanting and growing will be much better in humid or rainy climates. For example, I found that mosses stay wet longer for me if I do NOT put them on layers of felt, but can understand that downside where Rick Smith gardens, limestone soils may serve as a desiccant and dry the mosses more quickly and the felt would protect against that. The felt and plastic do help reduce weed invasion.

Weeding

Mashuri Waite (Bryonet 2 February 2011) expressed his surprise when visiting the Cibodas Botanical Garden in West Java, Indonesia. He found that a species of Marchantia (Figure 16) was a problem weed in that garden. This was in contrast to his experience in Hawaii. This is yet another example of differences in the success of a species of bryophyte under different growing conditions.

Weeds are also a matter of personal choice. To one person it is a weed; to another it is a cherished plant to be encouraged.

Weeding bryophyte gardens requires different methodology from gardens of flowers and ferns. The surface-growing bryophytes are easily dislodged as the weeds are pulled up. It is best to pull the weeds, especially tracheophytes, as soon as they appear and before they grow large roots. This will create the least disruption. When pulling them, especially if they have penetrated the ground very far, hold the plant to be pulled close to the ground and place the middle and index fingers of the opposite hand so that one is on each side of the base of the stem to hold the bryophyte in place as the rooted plant is pulled. Weeding should be done as often as necessary to keep the garden weed free.

Weeding is not as big a job as it may seem if it is done frequently. Young plants are easy to pull. And usually kneeling or stepping on the bryophytes does not harm the bryophytes and may even help to propagate them.

Herbicides

There actually are a number of publications on the effects of herbicides on bryophytes (e.g. Stjernquist 1981; Balcerkiewicz & Rusinska 1987).

Of course mosses are slow growing and soon succumb to the encroachment of tracheophytes, so it is no wonder that herbicide applications can result in luxurious moss carpets. Schenk (1997) has witnessed the ready success of Polytrichum (Figure 8, Figure 25-Figure 28), Pohlia (Figure 151), and Atrichum (Figure 3, Figure 92) following such applications, and Ella Campbell, at a bryological meeting, once commented that the hornworts were ready colonizers following herbicide applications. Likewise, Balcerkiewicz and Rusinska (1987) found that bryophytes expanded on areas treated with herbicides.

Weed-free.

Figure 151. *Pohlia nutans*, a species that seems to benefit from herbicide applications. Photo by Michael Lüth, with permission.

Herbicides such as Paraquat, Simazine (Bond 1976), 2, 4-D, Atrazine (D. H. Wagner, pers. comm.), and Roundup (Schenk 1997) will encourage moss growth by eliminating invading tracheophytes (Bond 1976). Weeding is of course a safer option, but be sure to hold the mosses down as you pull each weed to avoid disrupting the rhizoids too badly.

Ben Tan (Bryonet 15 April 2014) reported that experiments using herbicides and pesticides, conducted by his students, did not result in an easy kill of the mosses except at very high concentrations. He cautioned that if one does eliminate the mosses, aggressive flowering plants (weeds) will readily establish themselves.

But this is not the experience of all researchers. Rowntree et al. (2003) found that the herbicide Asulox inhibits moss growth. When they cut plants to a standard length and expose them to Asulox for 24 hours, they found...
that all 18 species tested exhibited reduced elongation. The amount varied among species and at different concentrations. The effective concentrations were the same as those effective on fern gametophytes. Rowntree and coworkers suggested that the ability to produce secondary branches might confer tolerance to single exposures of Asulox in some species.

In a different study, Rowntree et al. (2005) exposed cultures of *Bryum rubens* (Figure 152-153), *Campylopus introflexus* (Figure 141), and *Polytrichastrum formosum* (Figure 154) to Asulam in the culture medium. This study used protonemata that were exposed for 24 hours to Asulam, then transferred to herbicide-free media. A second trial maintained the protonemata on the herbicide medium for three weeks. In this case, the 24-hour exposure at concentrations of 0.001 g active ingredient L$^{-1}$ had no effect on growth or development of the mosses. However, all three species experienced reduced growth and developmental anomalies in continuous exposure at 0.01 g L$^{-1}$. *Campylopus introflexus* was the least sensitive; *Polytrichastrum formosum* was the most sensitive, with a 10-fold difference in response.

![Figure 152. *Bryum rubens*, a species for which development is affected by the herbicide Asulam. Photo by Michael Lüth, with permission.](image)

![Figure 153. *Bryum rubens* tubers that help the plants survive unfavorable conditions and produce new plants. Photo by Dick Haaksma, with permission.](image)

![Figure 154. *Polytrichastrum formosum*, a species for which development is affected by the herbicide Asulam. Photo by Michael Lüth, with permission.](image)

Karunen et al. (1976) exposed germinating *Polytrichum commune* (Figure 25) spores to S-ethyl dipropylthiocarbamate. Surprisingly, at low concentrations (2 ppm by weight), the herbicide actually stimulated the growth of the young protonemata compared to the controls. They had a higher chloroplast pigment content as well. When the concentration was increased to 100 ppm, however, the development was slowed and there was a 30% reduction of chlorophylls and carotenoids. Nevertheless, the dry weight did not differ significantly from that of the controls. At 200 ppm, the spores either did not germinate, stopped germinating at an early stage, or formed deformed sporelings with few tightly-packed short cells. A number of unusual morphological changes occurred. A concentration of 300 ppm the spores rarely germinated.

Dichlorophen (2, 2'-methylene-bis(4 chlorophenol)) is a commercial product used to eliminate bryophytes (Brown et al. 1986). Brown and coworkers experimented with the pleurocarpous moss *Rhytidialesphilus squarrosum* (Figure 2) and the thallose liverwort *Marchantia polymorpha* (Figure 16). Dichlorophen induces loss of intracellular potassium and magnesium, inhibits photosynthesis, and depending on concentrations either stimulates or depresses CO$_2$ production in the dark. These symptoms suggest membrane damage. Tissue age affects the sensitivity, but light does not.

Rod Seppelt (Bryonet 17 April 2011) reported that an Australian student had studied the effects of herbicides on mosses. The student concluded that it was the surfactants in some herbicides that provided the damaging factor. But he concluded that bryophyte response to herbicides was complex.

Using 115 plots in a randomized design, Newmaster et al. (1999) compared the effects of two silvicultural herbicides (Vision®, Release®) on bryophytes and lichens in a harvested boreal mixed woodland. Concentration gradients of 0.71-6.72 kg active ingredient ha$^{-1}$ caused a decrease in species richness and abundance in both groups. Only a few species of colonizers remained. Bryophytes and lichens could be sorted into herbicide-tolerant colonizers, semi tolerant long-term stayers from dry open forest, and sensitive forest mesophytes.
Bryophyte "Predators"

Bryophytes are not without their share of enemies – playing roles with impacts that few ecologists have begun to imagine. I couldn't keep mosses in my garden room – even when I brought in vast quantities; my finches soon spread them about the room in their efforts to carry them to their nests, but even the dispersed mosses were soon removed by the birds. Newly established protonemata are soon disrupted and destroyed by birds gathering new plants or scratching for grit. In my terrarium, the pillbugs (*Porcellio scaber*; Figure 155) eradicated them from the rocks completely in just a few weeks, and the beautiful carpet I draped on a rock outside was transformed literally overnight into the look of Swiss cheese. Picking up the moss carpet to understand the problem resulted in hundreds of pillbugs falling to the ground! As mentioned earlier, those wanting to use moss they collect are often encouraged to spray a 50% mix of buttermilk and water on the desired surface and then presumably spread a moss carpet over it, but I tried a similar recommendation of raw eggs to little avail. It was that patch of moss that became devoured by pillbugs and I suspect the egg helped make it so.

To keep your bryophyte garden healthy and green, Mizutani (1975, 1976) and Fukushima (1979a, b, 1980) advise eliminating potential destroyers such as moles (Figure 156), slugs (Figure 157), crickets (Figure 158), and ants (Figure 159). Good luck!
A second concern may be introducing pests from other locations, especially outside the country. Bryonetters discussed this several years ago, but many of the reports covered what didn't work. Among these, Eva Krab (Bryonet 3 February 2012) reported using 100% CO₂ for 12 hours in a closed chamber, then leaving the cores of moss out at room temperature for 24 hours to allow eggs to hatch, then freezing them at -20°C. After three rounds of those treatments, she had no success with *Sphagnum fuscum* (Figure 20) and only limited success with *Hylocomium splendens* (Figure 58).

Other Pests

Rick Smith, on Bryonet 9 February 2011, claimed that "birds have so much time on their hands they relentlessly attack moss gardens and unless the botanic garden has lots of moss then the birds concentrate their damage on the small poor moss garden." My own experience is that chipmunks can be just as destructive. They need only run across the bryophytes and their feet kick them up. And they seem to have a special attraction for *Thuidium delicatulum* (Figure 43-Figure 45) as the entrance to their tunnels. Mine never lasted for more than a few days before it had a bare spot and a tunnel entrance in the middle of it! I'm fairly certain that was a chipmunk, but some of those torn up patches may have been the work of birds instead of chipmunks. The fresh patches of mosses seem to attract the most attention. Perhaps it is due to birds looking for food among the fauna. Rick Smith also warned that "other obstacles are rodent damage (vole, squirrel, raccoon) and leaf removal."

Rick Smith has written a small book, *New Methods in Moss Gardening*. In that book he explains using an invisible mat system to reduce the unwanted interaction. He places felt (Figure 162) on the bottom – 2-3 layers, to block the competing vascular plants from emerging and to keep the soil from wicking the water away. On that he grows the mosses with a net on top to keep the birds and rodents from tearing it up. I have not had much success with the felt, but I think the problem is that I start with clumps of moss and Rick starts with tiny pieces that he broadcasts on the felt, then grows them in controlled conditions until they are large enough to put in the garden. I did try that once, but mine dried out too quickly. His method is much like grabbing that discarded carpet that has accumulated bits of soil and a healthy growth of mosses. But for thicker mats where tree seeds can lodge, seeds still germinate and succeed.

Overwatering can have some interesting invertebrate consequences. Too much water encourages earthworms to live closer to the surface, resulting in castings (Spain 2012b). If this is a moss garden with thin mats, the castings are deposited on the moss (Figure 160). When these are numerous, as they can be, they become unsightly. The prevention is to decrease the watering.

Netting

The netting is another story. One recommendation is to use a fine net with a mesh of about 0.8 mm such as a bridal veil, a material known as tulle, to keep rodents and birds from disrupting the bryophytes. But bridal veil is unsightly. Instead, I started with a fine mesh like one might find on a wedding veil, but instead of the soft cloth of wedding veils, I chose nylon window screening because it was not so conspicuous. That protected the mosses from rodents and birds, but for some of the mosses it kept them from getting wet unless it was a downpour. The water would bead up on top of the screen (Figure 161-Figure 162) and its cohesion kept it from penetrating. Sometimes cohesion and adhesion work to disadvantage!
Polytrichum (Figure 8) had particular problems with the nylon window screening. It often bent over instead of growing through the mesh (Figure 163-Figure 165), and the water beaded up on top of the net. In the morning when dew was on the net, the mosses were invisible. The next growing season some of the narrower young shoots grew through the net, but setae formed the previous autumn were trapped under the net (Figure 166). Finally, all the growing tips were above the netting that spring (Figure 167). But even then, water movement was not normal because of the constricting threads at the point where the moss penetrated the net. And if the mosses grow through the net, the netting can never be removed. Now, seven years later, the net is hidden and the mosses appear to be normal (Figure 168).
Rick Smith (Bryonet 30 August 2010) solved the constriction problem by placing the net over moss fragments so that they grew through it while they were still small and thin. Young (small) plants will grow through the bird netting, but so do some young weeds, and they are pretty impossible to pull out by the roots and to get out of the netting.

One solution to this problem is to put bird mist netting over the bryophytes instead. Susan Moyle Studlar (Bryonet 6 February 2012) considers netting to be essential to keep birds out. In her West Virginia, USA, garden, the birds toss the mosses about "with abandon" in search of the invertebrates beneath them. She found that the Berlin Botanic Garden used bird netting to protect the bryophytes from birds (Figure 169).

I finally solved the problem by ordering bird mist netting. It has a mesh about 5-6 mm and is made of fine black plastic. I hold it in place and help it conform to the uneven surface by pinning it down with bobbi pins. Once it is firmly attached, it is invisible unless you are looking for it or are up close. This type of netting is less conspicuous and doesn't interfere with growth (Figure 170-Figure 171). It must be firmly attached at its edges or the mosses will still be susceptible to disturbance and the netting can come off. Some birds may even try to remove it for nesting material.
Removing Autumn Leaves

Most of the bryophytes will need partial shade. But in a relatively small space, the best shade is likely to come from one or two deciduous trees. And these dump enough leaves in the fall to bury the bryophytes. The leaves do not decay rapidly enough to expose the bryophytes the next spring, and some seem to suffer from the tannic acids during the winter under the snow. Hence, removal is necessary.

Famous gardens such as Saihoji in Kyoto require constant maintenance to encourage the mosses against the competing tracheophytes. Leaf litter and weeds must be removed lest the mosses be crowded out, but care must be taken to maintain the natural, unmanicured look. Wire or bamboo rakes or soft brooms (Figure 172) are used for such maintenance; brooms should be firm but not harsh to reduce damage to the delicate moss leaves. There is a Japanese saying that only old men and little boys can tend the moss gardens because anyone else would be too careful and the gardens would lose their natural look (Takaki, pers. comm.; Figure 173).

Benner avoids raking leaves by covering the mosses with netting (Dunn 2008). He then collects the leaves and puts them in his compost heap.

Modern technology offers other solutions. One can vacuum the leaves or blow them onto a pile or onto flower gardens where they serve as a mulch (Figure 174). Annie Martin suggests watering the moss garden first when blowing them. The mosses will stay put, but the leaves will still blow. Use an up and down jerky motion to dislodge the leaves.

The modern methods of vacuuming the leaves have their limitations. Vacuuming is best done when the leaves are dry, and in some areas there are few dry days at that time of year or in some years. One must be careful not to blow or suck up dry mosses that are not well-connected yet. But then, even raking or brushing the leaves away is best done with dry leaves to protect the bryophytes from being removed.

Overwintering

Generally the predominantly perennial mosses will come through winter just fine. And in most cases, they will look bright green as soon as the snow recedes, being the earliest of the green plants to appear (Figure 175).
Figure 175. *Dicranella heteromalla* and *Atrichum* sp. demonstrate the fresh condition exhibited by many kinds of mosses that have just been uncovered from winter snow. Photo by Michael Lüth, with permission.

But don't despair if your moss garden comes out from under the snow the next spring looking like soon-to-be fossils. With a few warm (not hot) days and plenty of water, new shoots arise above the pathetic remnants of last year. My *Leucobryum* (Figure 34), *Polytrichum* (Figure 8, Figure 176), and *Fissidens* (Figure 48) did just that. The *Racomitrium* (Figure 53) remained brown and dead-looking for a long time, and I was ready to replace it with something more friendly when tiny green tips began to appear. There is nothing like a personal garden to teach you the trials and tribulations of the bryophytes and their ways of solving these problems. And *Marchantia polymorpha* thalli are green and healthy when the snow recedes in the spring. It will be interesting to see how the competition plays out. I think *Marchantia* (Figure 16) is going to win.

Figure 176. *Polytrichum* sp. in snow. Photo by Annie Martin <www.mountainmoss.com>, with permission.

**Arranging the Garden**

Give some thought to the arrangement of the mosses and other plants. For the mosses to offer their peaceful appeal, flowering plants must be kept at a minimum. One long-blooming highlight is enough for a garden of 4m², and it should be set off to the side or back to avoid detracting from the mosses (Figure 177). Be sure the plant won't crowd the ground, lie on top of the moss, or prevent light and/or water from reaching the moss. And avoid things that lose lots of leaves, requiring raking. As an alternative, lamps or statues can serve as highlights (Figure 178).

Figure 177. Moss garden with geranium accent. In early spring the irises on the right will bloom and be the accent. Photo by Janice Glimé.

Figure 178. A small painted clay lantern provides a highlight in this garden when the flowers have stopped blooming. Netting over some of the mosses has water beads on the netting. Photo by Janice Glimé.

Most mosses will need light shade, especially in the afternoon. A small tree, large shrub, building, or fence can provide this (Figure 179).
The benefit of mosses in the garden can extend beyond their aesthetic value to that of enhancing the quality of other garden plants. Schenk (1997) reports that his friend, Gordon Emerson of Ohio, finds that bulbs, tubers, and corms increase more readily under moss cover than when planted in bare ground. Presumably the increased moisture permits them to produce and store more energy.

### Environmental Benefits

I have already noted the decrease in water usage need by a moss garden vs a grass lawn. The bryophytes can often provide other solutions to environmental issues, such as collecting and preventing water run-off from storms. They also require no pesticides, herbicides, or fertilizers, therefore avoiding the contamination of the water that filters through them.

### Acknowledgments

I must acknowledge many Japanese friends for their tours of Japanese gardens and explanations of the establishment and care. In particular, Zen Iwatsuki and Norio Takaki gave me wonderful tours of both public and private gardens, indoors and out, and explained to me in English what the Japanese gardeners were telling us about the care of the gardens and plantation.

Thank you Ken Kellmann and Steve Soldan for calling our attention to the delightful New York Times article on moss lawns.

### Literature Cited


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GARDENING: PUBLIC GARDENS

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CHAPTER 7-5
GARDENING: PUBLIC GARDENS

Figure 1. Jassy moss house. This unusual garden transports you into another world. Photo courtesy of Ben Tan.

Botanical Gardens

Botanical gardens often have a bryophyte section, sometimes mimicking a Japanese garden. Some use mosses around indoor or outdoor waterfalls. And some actually label the bryophytes for teaching purposes. As you might guess, this latter practice can be seen in Japan.

Bryophyte gardening has been somewhat limited in North America, but there are notable exceptions. One of these is promoted by Rick Smith, who teaches moss gardening by offering workshops.

As a result of his workshops, Smith was invited to establish a moss garden at the Luthy Botanic Garden in Peoria, Illinois, USA, and a second at the Illinois Central College Arboretum in East Peoria. Both of these gardens have *Dicranum scoparium* (a dark green moss forming cushions; Figure 2), *Polytrichum commune* (Figure 3), *Bryoandersonia illecebra* (Figure 4), *Leucobryum glaucum* (Figure 5), *Hypnum* spp. (Figure 6), *Thuidium delicatulum* (a species that spreads easily; Figure 7), *Anomodon attenuatus* (Figure 8), and *Plagiomnium cusidatum* (Figure 9).

Figure 2. *Dicranum scoparium* with capsules, a common species in moss gardens, public or private. Photo by Janice Glime.
Figure 3. *Polytrichum commune*, a moss frequently occurring in moss gardens. Photo by Alan J. Silverside, with permission.

Figure 4. *Bryothamnion illecebra*, a moss from the southeastern USA and used by Rick Smith in moss gardens. Photo by Bob Klips, with permission.

Figure 5. *Leucobryum glaucum*; this genus is used in moss gardens all over the world. Photo by Janice Glime.

Figure 6. *Hypnum imponens*, a common sheet moss that appears in moss gardens. Photo by Janice Glime.

Figure 7. Fern moss, *Thuidium delicatulum*, a suitable moss for moss gardens. Photo courtesy of Rick Smith.

Figure 8. *Anomodon attenuatus* on trees, a common species in somewhat alkaline areas. Photo by Janice Glime.
Rick Smith (Bryonet) reports that he uses the mat system in both his own private garden and in public gardens. He uses a thin synthetic mat that stores rainwater similar to the storage by a sponge. As the moisture evaporates from the mosses, they draw more water from the underlying mat. He does not water his gardens, but in many climates watering is necessary, especially when the bryophytes are first getting established. He recommends only rainwater if watering is necessary, but occasional watering with other sources such as distilled water usually won’t harm the garden if it is interspersed with frequent natural watering.

George Schenk has moss gardens in Seattle, Washington, USA, New Zealand, and the Philippines, all areas that receive considerable annual rainfall. His book on Moss Gardening received the 1997 Horticultural Society of America’s book of the Year Award. Amazon says of the book "A delightful book that encourages gardeners to pay closer attention to the subtle beauty of miniature landscapes and introduces one of the glories of Japanese gardens into American designs. The author writes entertainingly of mosses on rocks and walls, in containers, and as a lush ground cover, and he presents a gallery of his favorite moss species."

Problems in Public Gardens

Rick Smith (Bryonet 9 February 2010) admonished that the challenge in most public gardens is growing bryophytes in urban areas vs. their natural woodland setting. Traditional moss gardens require a staff to weed the garden of the tracheophyte seedlings.

In public gardens, the gardeners are also the problems. They want to treat the bryophytes like "small vascular plants" that need to be watered and fertilized, but these are just what one must avoid. Care is primarily that of removing unwanted plants and leaf litter.

One additional problem in public gardens is human traffic. Although Annie Martin frequently points out that you should walk on your bryophytes to help in their dispersal, they are not equipped to withstand the parade of an army of people or small children playing tag. This presents the need for paths. These can be presented in a variety of ways, as you will see in the images in this chapter. Sand paths are common, but stone paths can be works of art themselves, with bryophytes filling the spaces between the stones. Wooden steps, including logs, provide niches for additional bryophytes. Care must be taken that there is no smooth wood that might invite algae, hence becoming slippery and a safety hazard.

Moss Gardens of the World

Dale Sievert has visited many gardens, large and small, and has kindly contributed his images for this chapter. This is but a small sampling of moss gardens in the world.

Bloedel Reserve, Washington, USA

The Bloedel Reserve is a 60.7-hectare (150-acre) forest garden on Bainbridge Island in the state of Washington, USA, first opened to the public in 1988. There one can find beautiful mossy landscapes. It includes a Japanese garden with a sand, moss, and rock garden, but many of the bryophyte landscapes in the reserve have a more natural look (Figure 10-Figure 11).

Seattle Japanese Garden, Seattle, Washington, USA

The Seattle Japanese Garden occupies 1.4 hectares (3.5 acres) in the Madison Park neighborhood of Seattle. It was designed under the supervision of the Japanese gardener Juki Iida in 1960. It features pools, streams, bridges, lamps, and the beautiful autumn color of Japanese maples, along with bryophytes (Figure 12-Figure 13).
Portland Japanese Garden, Portland, Oregon, USA

This garden is considered to be the most authentic Japanese garden outside of Japan. It occupies 2.2 hectares (5.5 acres) in the scenic west hills of Portland. The garden was designed by Professor Takuma Tono. One can see crooked paths, waterfalls, arched bridges, moss-covered lanterns, pools with koi, and other features often found in the gardens in Japan. Bryophytes are a prominent feature (Figure 14-Figure 16).

Anderson Japanese Garden, Rockford, IL, USA

These gardens are considered to be premiere among American Japanese gardens (Figure 17-Figure 19). They were established in 1978 when John Anderson, a Rockford businessman, was inspired by his visit to the Portland Japanese Garden. The design was assisted by Hoichi Kurisu, using the Anderson's swampy backyard. With 12 acres of gardens and koi-filled pools, this setting is often used for both peaceful reprise and weddings.
Golden Gate Park, San Francisco, California, USA

Starting with sand dunes, William Hammond Hall (a park engineer) and master gardener John McLaren created a restful place to escape the bustle of the city. The Golden Gate Park is a large urban park of 411.6 hectares (1,017 acres). In addition to its conservatory of flowers, it presents a Japanese tea garden, an oak forest, a botanical garden that began in 1890, and two Dutch windmills that pump the water to irrigate the garden (Figure 20-Figure 21). More than 8000 varieties of plants occupy the gardens.

Zion National Park, Utah, USA

Zion National Park covers 593 km² (229.1 mi²) and is characterized by rivers in deep canyons, colorful stone cliffs, waterfalls, and fantastic views. Despite the xeric nature of most of the park, one can still find bryophytes there (Figure 22). In 1909, the area was established as a National Monument by President William Henry Taft. But its name of Mukuntuweap National Monument drew criticism because it was difficult to pronounce. In 1918 it was renamed to Zion, the name that had been used by the Mormons who settled there. In 1919 it was established by The United States Congress as a national park.

Missouri Botanical Garden, St. Louis, Missouri, USA

The Missouri Botanical Garden was founded in 1859 and is the oldest botanical garden in the USA. The garden is comprised of 32 hectares (79 acres) and includes a Japanese strolling garden (Seiwa-en) of 5.7 hectares (14 acres). Designed by Koichi Kawana, this is the largest Japanese garden in North America (Figure 23).
Rotary Botanical Garden, Janesville, Wisconsin, USA

The Rotary Botanical Garden in Janesville is an 81 hectare (20-acre) reprise. Bryophytes can be seen along some of the paths and in the Japanese garden, and some have managed to establish themselves between the stones of the paths (Figure 24). Of interest to the bryologists is the fern and moss garden.

Sarah Duke Gardens, Durham, North Carolina, USA

The Sarah Duke Gardens comprise approximately 22 hectares (55 acres) of landscaped and wooded areas at Duke University. There are 5 miles of allées, walks, and pathways throughout the gardens. The official beginning of the gardens was 1934, when Dr. Frederick Moir Hanes, a faculty member at the Duke Medical School, persuaded Sarah P. Duke to provide $20,000 toward planting flowers in a debris-filled ravine. But alas, the gardens were destroyed in 1935 by a flood. Sarah Duke's daughter provided funds to rebuild the gardens above the flooding zone as a memorial to her mother, who died in 1936. In parts of the gardens, the ground is covered by a restful green mat of bryophytes (Figure 25).

Limahuli Gardens, Kauai, Hawaii, USA

The Limahuli Gardens are part of the Limahuli Preserve and occupy 6.9 hectares (17 acres) among the 399 hectares (985 acres) of the preserve. The gardens were built to "honor the connection between nature and humanity." This is in one of the last easily-accessible valleys where native forest, pristine streams, and archaeological complexes remain. The descendants of its original inhabitants are its caretakers. In 1967, after Hawaii became a state, Juliet Rice Wichman, a member of the Hui, was assigned to develop the new park. She immediately began to plan and plant. She bequeathed the gardens to one of her grandsons. Since its beginnings it has been awarded "Best Natural Botanical Garden" from the American Horticultural Society for demonstrating the "best environmental practices of water, soil, and rare plant conservation in an overall garden design" and the Koa Award for dedication to the perpetuation of the Hawaiian culture. Bryophytes contribute to the lushious natural landscape (Figure 26).

Sikkum, India

In Sikkum, one can find many walls with mounds of mosses growing on the sides and tops. Waterfalls are green with bryophytes. And bryophytes adorn the forest floor and branches (Figure 27-Figure 28).
Floriade, Venlo, Holland

This garden at Floriade represents modern architecture that utilizes bryophytes in the design (Figure 29).

Villa d'Este, Tivoli, Italy

The Villa d'Este is near Rome, Italy. It is adorned with numerous fountains, some of which are covered with bryophytes (Figure 30).

Herculaneum, Italy

Herculaneum rests in the shadow of Mount Vesuvius. It was an ancient Roman town destroyed in 79 AD by volcanic pyroclastic flows. Only ruins remain of the ancient town, and ruins often provide suitable substrates for bryophytes (Figure 31). But more recent statues may be covered with bryophytes (Figure 32).
Educational Displays

A number of gardens serve educational needs. This may be the entire garden, or only small portions. This education is usually accomplished by signs. Some gardens include a feel garden, especially pitched toward the blind, but can also be attractive to children. Mosses offer a wide range of textures that can be a delight to those meeting them for the first time. Additional information can be provided in Braille.

The Moss House (Figure 33-Figure 34) in India is designed for teaching. The bryophytes are planted and the species patch is outlined with white rocks (Figure 35-Figure 36). A label is placed on a stake in the patch. A simpler design without the feel of a garden is to plant bryophytes in pots and provide them with a label (Figure 37).

Indoor gardens like the Moss House require watering. This is best done with an automatic misting system (Figure 38), but care must be taken to create the appropriate regime. A filtering system might be needed to remove chlorine and unwanted minerals from the water. A fan may be needed to prevent mold.
Summary

Public gardens occur all over the world, and many have sections with bryophytes, especially in Japanese gardens. These bryophytes require caretakers who understand the differences in the needs of bryophytes, avoiding fertilizers and maintaining boundaries between species. Watering may also be necessary.

This chapter has only a small sampling of public gardens with mosses, including some that have attempted to mimic the Japanese gardens.

Acknowledgments

Dale Sievert made this chapter possible with his images of gardens with mosses from all over the world, and especially from North America. Virendra Nath contributed images from the Moss House that formed the basis of the Educational Displays section.

Labelling

In an arboretum labels help us to learn the names of the trees. Few gardens exist where a similar education is available for bryophytes. I quickly learned one of the problems of providing such labels for bryophytes. I learned that the field trip I had been asked to lead would have 60 participants. I went armed with a stack of pink computer cards. At each bryophyte, I placed a card with the name of the species. But the bryophytes were small and the cards were large. Many of the cards touched several species. That is only part of the problem in a bryophyte garden. As time passes, the species that is labelled can expand or get overgrown by other bryophytes. Furthermore, to most people, all bryophytes look pretty much the same. One Botanical Garden has attempted to solve the problem by locating a large patch of the bryophyte and attaching a label, then posting information explaining the characters used to identify the bryophyte and providing other useful information about it (Figure 39).