CHAPTER 7-4
GARDENING: MOSS GARDEN DEVELOPMENT AND MAINTENANCE

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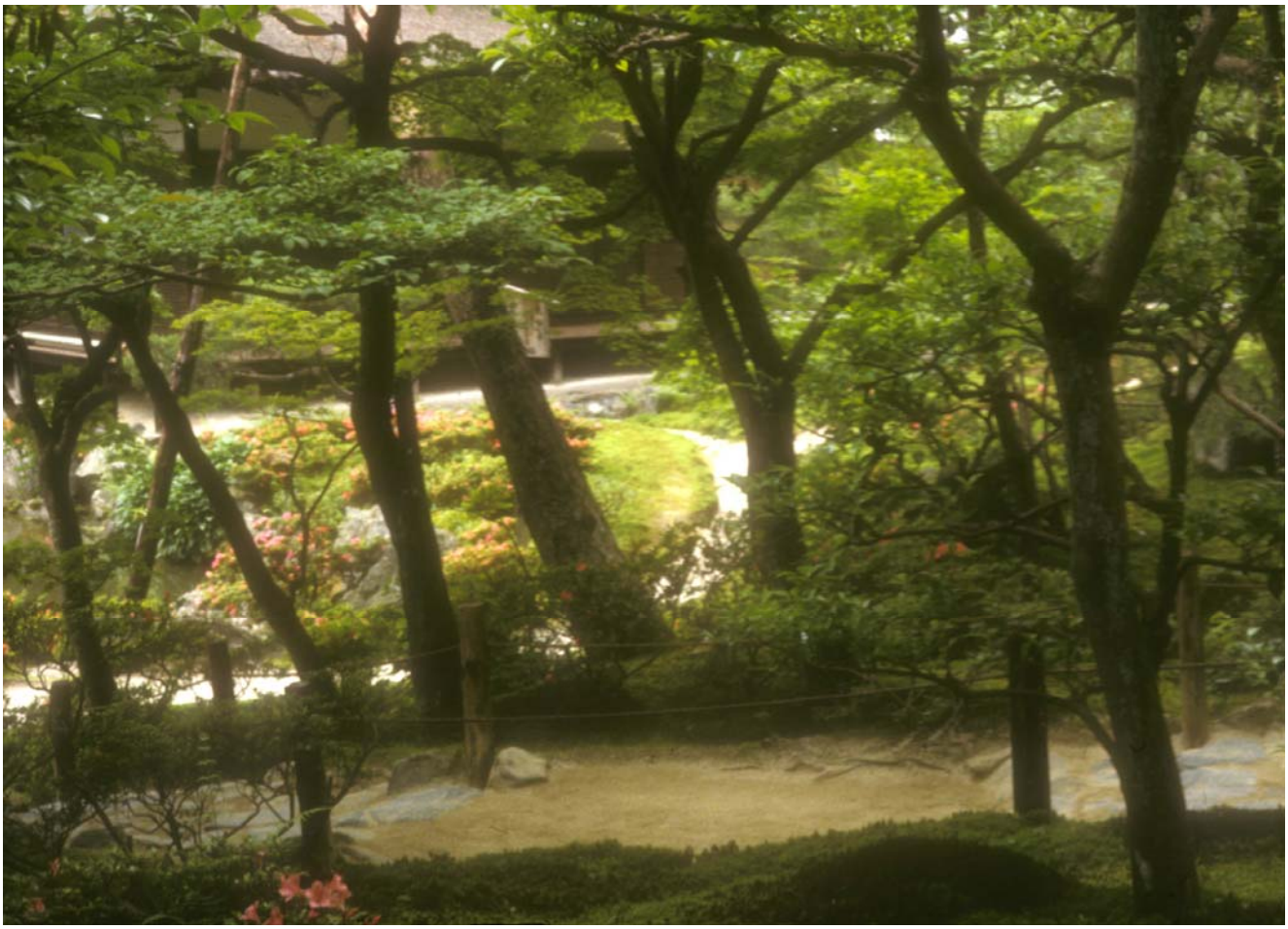

Figure 1. This moss garden in Kyoto, Japan, takes advantage of a stream to add to its peaceful nature. Photo by Janice Glime.

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.

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.

Figure 7. The moss ***Didymodon vinealis*** is often found on rooftops, concrete, and rock walls. Photo by Michael Lüth, with permission.

Figure 8. ***Polytrichum juniperinum***, a moss that does well on west-facing slopes. Photo by Jan-Peter Frahm, with permission.

Figure 9. ***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), ***Racomitrium 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.

Figure 10. ***Syntrichia ruralis***, a species tolerant of bright sun and desiccation. Photo by Janice Glime.

Figure 11. ***Homalothecium sericeum***, a common species in Europe. Photo by Janice Glime.

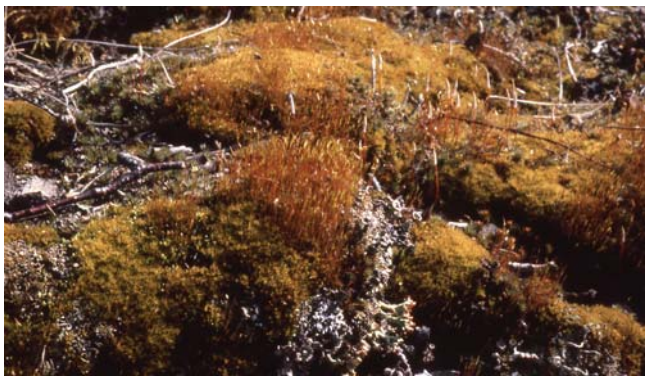

Figure 12. ***Ceratodon purpureus***, a widespread and sun-tolerant species that adapts well to a controlled environment. Photo by Janice Glime.

Figure 13. ***Grimmia pulvinata*** on wall, a moss that is widespread and common on walls and rock. It also grows well in controlled environments. Photo from Botany Department Website, UBC, Canada, with permission.

Figure 14. ***Racomitrium aciculare***, a rock-dwelling moss. Photo by Michael Lüth, with permission.

Figure 15. ***Bryum capillare***, a common moss with a wide distribution. Photo by Des Callaghan, with permission.

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). 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).

Figure 16. ***Marchantia polymorpha*** with its umbrella-like **archegoniophores**, a species that spreads easily on disturbed soil. Photo by Janice Glime.

Figure 17. ***Lunularia cruciata***, a species that is common in greenhouses in the USA, but can be grown in moss gardens. Photo by Des Callaghan, with permission.

Figure 18. ***Conocephalum conicum***, a thallose liverwort that multiplies rapidly and can be dispersed by turtles and other fauna. Photo by Janice Glime.

Figure 19. ***Riccia sorocarpa***, a common thallose liverwort. Photo by Michael Lüth, with permission.

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 *p*H 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.

Figure 20. ***Sphagnum fuscum***, a species that lives on tops of hummocks. Photo by Michael Lüth, with permission.

Sphagnum comes in a wide range of colors (Figure 21), and a bouquet of colors and hues can be arranged in the same garden by using some care in choices of species. Some of these may be maintained by placing them at greater distance from the water source, such as ***Sphagnum fuscum*** (Figure 20) (Fletcher 1991).

Figure 21. ***Sphagnum magellanicum*** and other species of ***Sphagnum*** showing some of the range of colors that occur together naturally. Photo by Janice Glime.

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.

Figure 22. ***Sphagnum quinquefarium***, a moss of well-drained slopes in forests. Photo by Michael Lüth, with permission.

Figure 23. ***Sphagnum cuspidatum***, an emergent species for pools. Photo by Jan-Peter Frahm, with permission.

Figure 24. ***Sphagnum compactum***, a species that grows on wet sand or rocks in shaded areas where it tolerates drying. Photo by Michael Lüth, with permission.

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.

Figure 25. ***Polytrichum commune*** var ***commune***, a common species used in moss gardens. Photo by David Holyoak, with permission.

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.

Figure 26. ***Polytrichum piliferum*** males, adding a bit of color to moss gardens in spring. Photo from Proyecto Musgo, through Creative Commons.

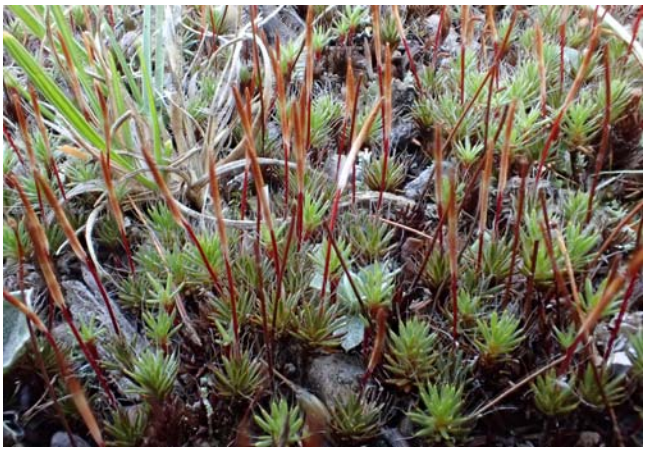

Figure 27. ***Polytrichum piliferum*** with young sporophytes. Photo by Janice Glime.

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.

Figure 28. ***Polytrichum strictum*** with capsules, a bog/fen species that is suitable for moss gardens. Photo by Michael Lüth, with permission.

Atrichum

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.

Figure 29. ***Atrichum altecristatum*** leaf portion showing lamellae over costa down center. Photo by Bob Klips, with permission.

Figure 30. ***Atrichum altecristatum*** showing lamellae over costa in leaf cross section. Photo by Bob Klips, with permission.

Figure 31. ***Atrichum altecristatum*** along a path in the forest in Houghton, Michigan, USA. Photo by Janice Glime.

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.

Figure 36. ***Leucobryum glaucum*** showing dead lower parts that sit on the soil surface. Photo courtesy of Diane Lucas.

Leucobryum bowringii (Figure 37), ***L. juniperoideum*** (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.

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

Figure 38. ***Leucobryum juniperoideum***, 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.

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

many parts of the world, permitting its use in the moss gardens of Japan.

Figure 40. ***Dicranum scoparium*** on forest floor, a common moss of forests that adds a dark green to the garden. Photo by Janice Glime.

Figure 41. ***Dicranum scoparium*** showing leaves curved in one direction. Photo by Janice Glime.

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).

Figure 42. ***Plagiomnium cuspidatum*** is easily grown if it can be transplanted without disturbing its connections to the soil and each other. Photo by Michael Lüth, with permission.

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

Thuidium delicatulum

Thuidium delicatulum (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.

Figure 43. ***Thuidium delicatulum*** when it is wet and fresh. Photo by Jan-Peter Frahm, with permission.

Martin (2010) finds this moss to be a strong grower in winter in North Carolina – in her words, growing "by leaps and bounds during the winter months." She found that it quickly spread over mosses like ***Leucobryum*** (Figure 34) and ***Dicranum*** (Figure 40), invading and sometimes covering these mounds.

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.

Figure 44. ***Thuidium delicatulum*** branch showing the projecting papillae on the leaves. Photo by Bob Klips, with permission.

Figure 45. ***Thuidium delicatulum*** dry (and crunchy). Photo by Janice Glime.

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.

Figure 46. ***Pseudoscleropodium purum***, a common moss in Europe, but invasive in parts of the USA. Photo by Janice Glime.

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.

Figure 47. ***Rhodobryum ontariense***, an attractive moss for gardens. It prefers alkaline habitats but also grows over sandstone rocks. Photo by Janice Glime.

The ***Fissidens*** (Figure 48) in my moss garden has spread to other gardens in my yard. It can be aggressive, as seen in Figure 49 where it is overgrowing ***Marchantia polymorpha***.

Fissidens

Fissidens (Figure 48) is not often mentioned as a genus for moss gardens. However, my experience with it is that it is an excellent choice. It holds up well and stays green when it is dry. But the best news is that it grows well when propagated and spreads by itself, perhaps with the help of the chipmunks.

Figure 48. ***Fissidens adianthoides*** is a moss easily cultivated by transplant or fragments. Photo by Michael Lüth, with permission.

Figure 49. ***Fissidens*** in my moss garden in Houghton, Michigan, USA, on 15 April 2010 soon after snow melt. Here it is taking over ***Marchantia polymorpha***. Photo by Janice Glime.

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 ***Rhytidiadelphus squarrosus*** (Figure 2) (Fletcher 1991).

Figure 52. ***Hypnum imponens***, a widespread species suitable for moss gardens. Photo by Janice Glime.

Figure 50. ***Pyrrhobryum dozyanum***, a large moss that does well in shady sites in Japanese gardens. Photo by Janice Glime.

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

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.

Figure 54. ***Hypnum plumaeforme***, an epiphyte in Japan. When planted in moss gardens, it requires frequent watering and weeding. Photo by Janice Glime.

Figure 55. ***Eurhynchium praelongum***, a beautiful plumose moss suitable for gardens. Photo by Blanka Shaw, with permission.

Figure 56. ***Rhynchostegium confertum*** with capsules, a species suitable for moss gardens. Photo by Michael Lüth, with permission.

Figure 57. ***Brachythecium rutabulum*** with capsules, a common moss that will grow in gardens. Photo by Michael Lüth, with permission.

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 ***Rhytidiadelphus triquetris*** (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.

Figure 58. ***Hylocomium splendens***, a species that does not transplant well. Michael Lüth, with permission.

Figure 59. ***Pleurozium schreberi***, a species that does not transplant well. Photo by Sture Hermansson, with online permission.

Figure 60. ***Rhytidiadelphus triquetrus***, a species that transplants well. Photo by Janice Glime.

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.

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

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 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.

Figure 66. ***Climacium americanum*** with capsules in moss garden. 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 adianthoides*** (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 Dundee (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.

Figure 67. Moss lawn near Minisink Lake, Bushkill, PA, USA. Photo by Janice Glime.

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. The following year the original clump was a forest of **archegoniophores** (structure where female gametes and ultimately capsules are produced; Figure 16).

My ***Marchantia polymorpha*** (Figure 16) sported a bevy of children in a 25-cm circle around the parent plants, products of gemmae 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.

Figure 68. ***Marchantia polymorpha*** gemmae cups with gemmae. Photo by Dick Haaksma, with permission.

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.

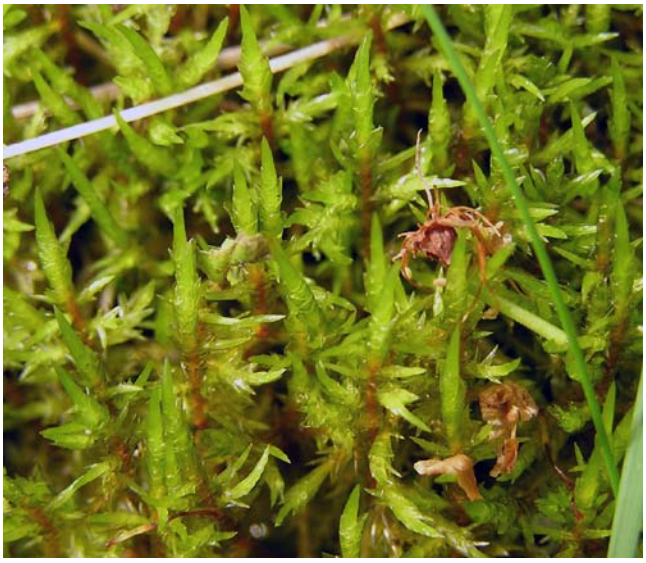

Figure 69. ***Calliergonella cuspidata***, a species that does well in lawns and gardens in Europe, but not in North America. Photo by Michael Becker through creative Commons.

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.

Figure 70. ***Brachythecium rutabulum*** showing setae that support the capsules. Photo by David Holyoak, with permission.

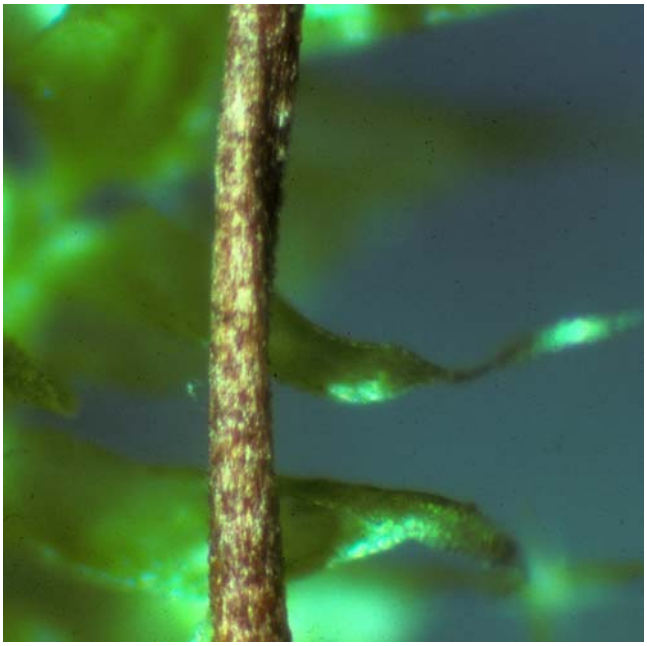

Figure 71. ***Brachythecium rutabulum*** papillose seta. The papillae are best seen along the lower sides of the seta in this picture. Photo by Janice Glime.

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).

Figure 72. ***Campylopus flexuosus*** showing senesced lower parts of plants upon which the active parts are able to grow. Photo by Michael Lüth, with permission.

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.

Figure 73. ***Bryum argenteum***, a common lawn species that propagates from fragments from the tips. Photo by Michael Lüth, with permission.

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.

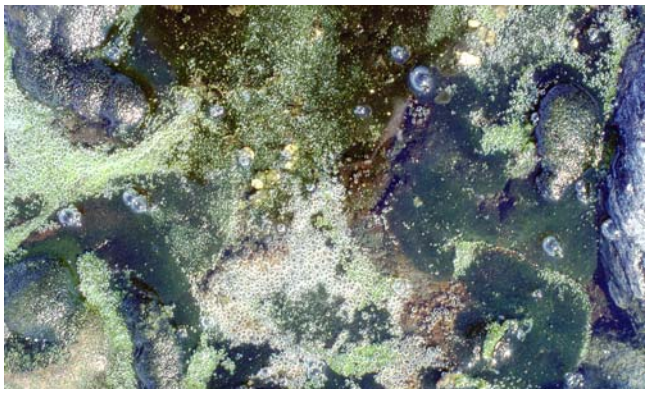

Figure 84. ***Ceratodon purpureus*** submersed with air bubbles at Casey Station, Antarctica. Photo courtesy of Rod Seppelt.

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).

Figure 86. ***Barbula unguiculata***, a common species between bricks and stones. Photo by Michael Lüth, with permission.

Figure 87. ***Barbula convoluta***, a common species between bricks and stones. Photo by Janice Glime.

Figure 88. ***Barbula cylindrica***, a common species between bricks and stones. Photo by Des Callaghan, with permission.

Figure 89. ***Barbula fallax***, a common species between bricks and stones. Photo by Kristian Peters, with permission.

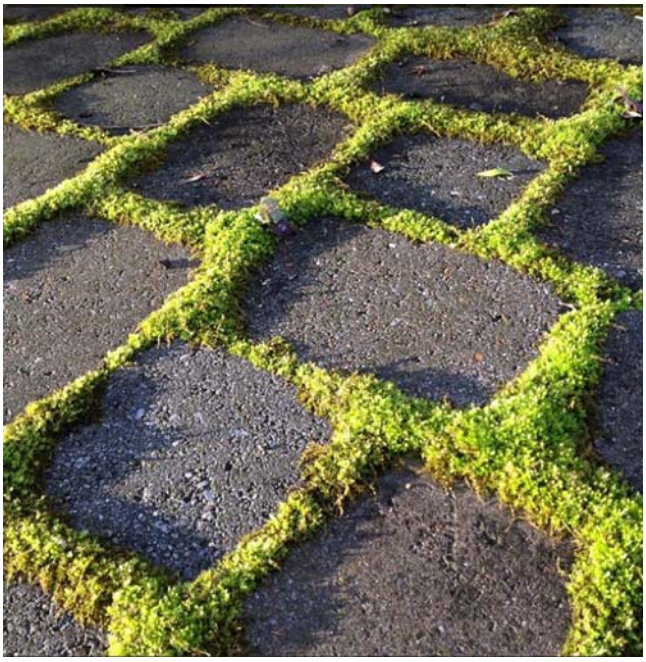

Figure 90. Mosses in pavement. Photo by J. Paul Moore, with permission.

Figure 91. ***Barbula unguiculata*** in the center, flanked by ***Conocephalum conicum*** at the top right, and ***Polytrichum juniperinum*** below it. Photo by Janice Glime.

Based on invasion of a newly cut ski trail, I would recommend ***Atrichum altecristatum*** (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.

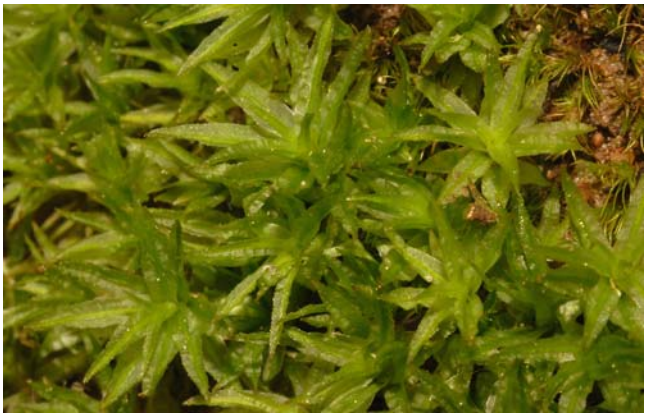

Figure 92. ***Atrichum altecristatum*** drying, a species tolerant of living on paths. Photo courtesy of Eric Schneider.

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.

Figure 97. ***Climacium americanum*** clipping to propagate. Photo by J. Paul Moore, with permission.

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.

Figure 98. Mats for planting mosses. The black layer is a synthetic felt with adhesive plastic backing. Photo by Annie Martin <www.mountainmoss.com>, with permission.

Figure 99. Close view of coco fiber mat and black felt for planting mosses. Photo by Annie Martin <www.mountainmoss.com>, with permission.

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.

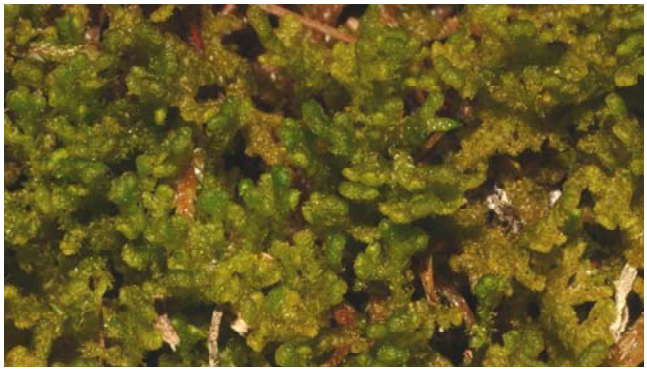

Figure 103. ***Ptilidium ciliare***, a moss successfully grown from dry fragments. Photo courtesy of Eric Schneider.

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), ***Plagiomnium cuspidatum*** (Figure 42), and ***Climacium 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.

Figure 105. ***Racomitrium canescens*** in its wet appearance. The pale green color adds a fresh look. Photo by Michael Lüth, with permission.

Figure 106. ***Climacium dendroides***, an attractive moss for moss gardens. Photo by Janice Glime.

Figure 107. ***Encalypta streptocarpa*** with capsules, a species that arrived in a Finnish moss garden by itself. 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.

Figure 108. ***Bryum*** sp. on burlap. Photo by Janice Glime.

Figure 109. ***Ceratodon purpureus*** and ***Bryum*** sp. on burlap. Photo by Janice Glime.

Figure 110. ***Ceratodon purpureus*** and ***Bryum*** sp. with partial netting on burlap. Photo by Janice Glime.

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.

Figure 111. Fragments of bryophytes on cutting board, ready to plant. Photo by Janice Glime.

Figure 112. Fragments that have been scattered on wet brown felt. Photo by Janice Glime.

Figure 113. Planting fragments of ***Polytrichum juniperinum*** on felt, underlain with visqueen. Photo by Janice Glime.

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.)

Figure 114. ***Hylocomium splendens*** in snow. Photo by Michael Lüth, with permission.

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).

Figure 115. ***Pogonatum japonicum***, a moss in a genus used in moss gardens in Japan. Photo from Digital Museum, Hiroshima University, with permission.

Figure 116. This plantation in Nagoya, Japan, uses pine trees to provide shade for growing mosses. Photo by Janice Glime.

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.

Figure 117. Stacks of ***Polytrichum*** are ready for delivery to a private garden near Nagoya, Japan. Photo by Janice Glime.

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^{o}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 adianthoides*** (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 adianthoides***, 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^{o}C) seemed more favorable than a higher light intensity and temperatures of 38^{o}C.

Figure 118. ***Atrichum oerstedianum***, a species that can be grown from fragments. Photo by Karen Renzaglia, with permission.

Figure 119. ***Plagiomnium affine***, a species that can be grown from fragments. Photo by Janice Glime.

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-Figure 121), ***Racomitrium*** (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***.

Figure 120. ***Leucobryum glaucum*** apical rhizoids, ready to grow if they get broken off. Photo courtesy of Sean Edwards.

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.

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 *p*H 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.

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

When the plants are well established (about 4 ½ 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.

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).

Figure 126. Sleds of mosses, in this case being transported for planting. Photo by Annie Martin <www.mountainmoss.com>, with permission.

Figure 127. Raleigh Project, loading moss in plastic flats into truck. Photo courtesy of Annie Martin <www.mountainmoss.com>.

Figure 128. Paul Moore planting mosses directly on the ground, using boxes to transport them. Photo courtesy of Paul Moore.

Figure 129. Janice Glime gathering moss for her garden. Photo courtesy of Eileen Dumire.

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 *p*H 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.

Figure 130. ***Cryptothallus mirabilis***, a thallose liverwort that requires a fungal partner to obtain carbohydrates. Photo by David Holyoak, with permission.

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.

Figure 131. Toothpicks holding transplanted mosses onto a clay bank. Photo courtesy of Annie Martin <www.mountainmoss.com>.

Figure 132. Moss pins from Moss and Stone Garden. Photo with permission from David Spain.

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.

Figure 133. ***Bryum*** sp. in moss garden. These mosses were touching tightly together when they were planted, but when they dried they shrank, creating spaces around the edges. Photo by Janice Glime.

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.

Figure 135. ***Ceratodon purpureus*** and ***Bryum*** sp. with stones to protect edges. Photo by Janice Glime.

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>.

Figure 137. Raleigh Project laying down sheet of moss. Photo courtesy of Annie Martin <www.mountainmoss.com>.

Figure 138. Cutting shape of the moss mat. Photo courtesy of Annie Martin <www.mountainmoss.com>.

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 *p*H of about 5.5, attainable by spreading powdered sulfur over the soil (about 1.1 kg per 9 m^2) (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.

Figure 144. Annie Martin demonstrates walking on mosses to help in fragmentation and dispersal. Photo by Annie Martin, with permission <www.mountainmoss.com>.

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 *p*H. 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.

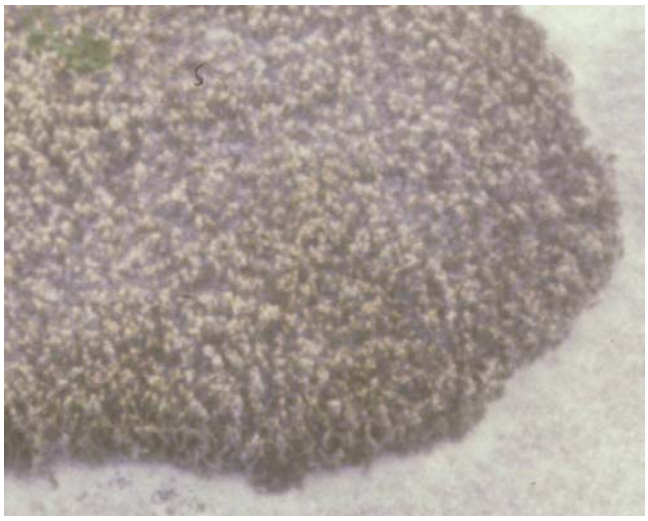

Figure 145. This ***Grimmia*** on Mt. Rainier, Washington, USA, is covered with ash from the eruption of nearby Mt. St. Helen's. The moss is badly desiccated by the ash that is like some fertilizers. Photo by Janice Glime.

Annie Martin (Bryonet 22 June 2013) raised the issue of fertilizing the mosses. First, fertilizers should be applied in very dilute watering additions. Fertilizers on dry mosses can further desiccate them. As in all other issues regarding bryophytes, bryophyte species differ in their responses. Annie Martin (Bryonet 22 June 2013) reported that in her early days of moss gardening experimentation, she watered with Miracle-Gro acid mix. However, when she learned of the dangers of fertilizers she switched to straight tap water only.

One additional problem with applying fertilizers is that flowering plants will benefit more than the mosses, thus introducing a greater weed problem.

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. *p*H 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

2010). He, like Martin, uses three layers of felt with plastic underneath and netting on top. Martin believes his success is due to watering six times each day for 4 minutes per watering session. He uses creek water in his misting system. Watering in unplanted areas also resulted in a carpet of thriving ***Plagiomnium*** that arrived by itself.

Annie 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 C_3 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 (Glime 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 downstate 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.

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-Figure 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 of 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.

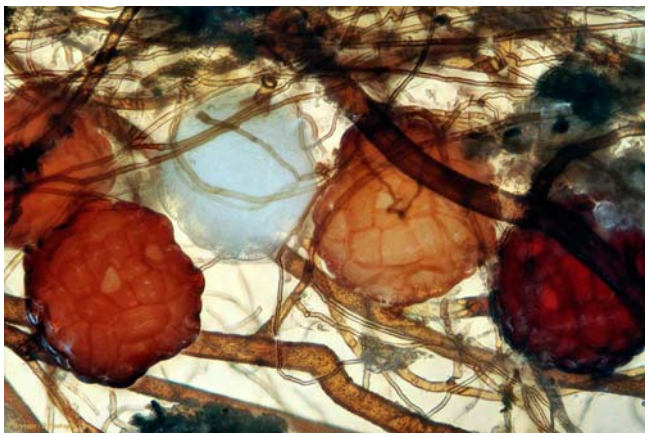

Figure 153. ***Bryum rubens*** tubers that help the plants survive unfavorable conditions and produce new plants. Photo by Dick Haaksma, with permission.

Figure 154. ***Polytrichastrum formosum***, a species for which development is affected by the herbicide Asulam. Photo by Michael Lüth, with permission.

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 ***Rhytidiadelphus squarrosus*** (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.

Figure 155. ***Porcellio*** *cf.* ***scaber*** on ***Marchantia polymorpha***, a common herbivore on bryophytes. Photo by Walter Obermayer, with permission.

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!

Figure 156. Mole, sometimes a pest in moss gardens. Photo by Michael David Hill, through Creative Commons.

Figure 157. Slug on ***Fissidens*** sp. Photo by Janice Glime.

Figure 158. ***Gryllus rubens***, southeastern field cricket. Crickets can be a pest in moss gardens. Photo by Jeffrey Reed, through Creative Commons.

Figure 159. Ant on moss, sometimes a pest in moss gardens. Photo through Creative Commons.

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% CO_2 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 -20ºC. 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.

Figure 160. Earthworm castings on a moss mat. Photo by Ken Gergle for Moss and Stone Gardens.

Earthworm castings can be removed by letting them dry and removing them with a knife or crumbling them (Spain 2012b). The remaining hard portion can be removed by using a pump sprayer to soften them and gently wash them away. Using a hose or other high-power sprayer should be avoided because it will make the moss and soil wet again, once again encouraging movement of the worms to near the surface.

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!

Figure 161. ***Bryum*** sp. on burlap with wet net in lower half of image. Upper mosses in image have no netting. Photo by Janice Glime.

Figure 162. Wet netting on ***Polytrichum commune*** that is planted on brown felt, showing the water beading on the net and not penetrating to the moss. Photo by Janice Glime.

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).

Figure 163. ***Polytrichum juniperinum*** under netting, showing how they have grown sideways due to the restriction of the netting. Photo by Janice Glime.

Figure 164. ***Polytrichum*** and fragments on felt under nylon window screening. Rocks hold the edges of the screening in place. Photo by Janice Glime.

Figure 165. ***Polytrichum juniperinum*** under netting after stems became more upright. Photo by Janice Glime.

Figure 166. ***Polytrichum juniperinum*** emergence through netting with sporophytes produced the previous growing season trapped beneath the netting. Photo by Janice Glime.

Figure 167. ***Polytrichum juniperinum*** emergence through netting after several years of growth. Note how it keeps the plants separated, reducing their ability to help each other transport and retain water. Photo by Janice Glime.

Figure 168. ***Polytrichum juniperinum*** in moss garden, November 2017. They are continuing growth above the netting, with netting completely hidden. Photo by Janice Glime.

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).

Figure 169. Moss garden in Berlin Botanic Garden, showing bird netting. Photo courtesy of Susan Moyle Studlar.

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 be 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.

Figure 170. ***Leucobryum glaucum*** moss garden with bird netting. Note the clumps that have been broken up – damage done before the netting was applied. Photo by Janice Glime.

Figure 171. ***Leucobryum glaucum*** with bird netting in moss garden. Photo by Janice Glime.

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).

Figure 172. This broom is used for tending a private moss garden in Japan. Photo by Janice Glime.

Figure 173. This "old man" tends moss in Ginkakuji temple garden in Kyoto, Japan. Photo by Janice Glime.

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 <https://www.youtube.com/watch?v=nh9S1IDfXzE&t=3s> 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.

Figure 174. Blowing leaves off the mosses. Photo by Annie Martin, with permission.

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 about 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 $4m^2$, 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 Glime.

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 Glime.

Most mosses will need light shade, especially in the afternoon. A small tree, large shrub, building, or fence can provide this (Figure 179).

Figure 179. A neighbor's garage, a cedar fence, lilac bushes, and a Japanese maple tree provide shade for this moss garden in the morning, with the garage and my house shading it in the afternoon. Photo by Janice Glime.

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.

Figure 180. ***Fontinalis antipyretica***, an aquatic moss that is sensitive to heat. Photo by Bernd Haynold, through Wikimedia Commons.

Summary

Among the most common "moss" garden plants are thallose liverworts, especially ***Marchantia polymorpha***, peat mosses (***Sphagnum***), ***Polytrichum***, ***Atrichum***, members of the **Mniaceae**, ***Leucobryum*** (but it is somewhat difficult), ***Rhizogonium*** in Asia, ***Rhytidiadelphus triquetris***, ***Eurhynchium*** (*sensu lato*), and ***Bryum argenteum***. *Fissidens* species seem to be particularly easy to grow in temperate North America.

Special habitats may support only a few species, including ***Rhytidiadelphus squarrosus*** and ***Brachythecium rutabulum*** for lawns, ***Bryum argenteum*** and ***Barbula*** for paths, and ***Tortula muralis*** for walls.

Mosses cultivated in containers will need plenty of ventilation. Flats are good starter containers, with the mosses later transplanted to a "plantation" with light shade. Both can be planted by pulverizing the plants and spreading them like grass seed. A sprinkling system may be needed in a climate without a rainy season, and one should take advantage of the rainy season, where it exists, by planting just before it so the young plants or transplanted ones get plenty of water.

When transplanting mosses from the wild, the integrity of the clump or mat must be maintained. Of course one must have permission, and care should be taken not to decimate the population.

The substrate may be amended with a variety of substances to lower the *p*H, but liming and fertilizers are detrimental to bryophyte health. Herbicides may eliminate tracheophyte competition, but hand care by pulling weeds and clearing away litter is most likely a safer choice. Avoid giving the garden a manicured look and use only a light broom or wooden rake to clear away litter. Winter care need be no more than removing deciduous litter.

Once established, the bryophytes will require less water than a lawn or flower garden, require no fertilizers or pesticides, and prevent erosion. They are more environmentally friendly than most kinds of gardens.

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