# SECRET BEAUTY OF FRESHWATER: ‘‘AQUARIUM MOSSES’’

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***ABSTRACT***

*Bryophytes are the oldest of all land plants and are believed to be the closest remaining link between land and aquatic plants. Their soft tissue makes fossil records bleak but the oldest evidence that has so far been found can be dated back to almost 500 million years ago. Spore-like structures of a liverwort were found in Argentinian rock dated to 473-471 million years old. The first evidence of mosses appears much more recently between fossils aged between 299-250 million years old. Due to the poor preservation of Bryophyte species, it is quite possible that the Bryophytes are significantly older.*

*The bryophytes are the second largest group, exceeded only by the Magnoliophyta – the flowering plants (350,000 species). Their nearest algal relatives appear to be members of the Charophyta. Bryophytes are generally considered the first land plants. The role of bryophytes in the ecosystem is significant despite their small size.*

*Aquatic mosses are generally chosen for their aesthetic qualities; they can also contribute to improved water quality. As photosynthesizing plants, aquatic mosses absorb nutrients in your aquarium water, including nitrates, from the water column. Where other plants require high light levels to accomplish this, or a regular fertilizing regime, aquatic mosses are effective nitrate removers without high light levels or fertilizer.*

***Key words****: Bryophytes, mosses, liverworts, hornworts*

## 1. INTRODUCTION

Bryophytes, nonvascular plants**,** the second largest group of terrestrial plants (15000-25000), very heterogeneous group of paraphyletic origin. Their ancestor was among the first land plant and cannot extensively transport water, sugar, and minerals (bryophytes lack true roots and leaves). they require moist environment for active growth and sexual reproduction. They rely on diffusion and osmosis to obtain water and dissolved nutrients (bryophytes lack well developed vascular tissue (xylem and phloem).

Land plants evolved from green algae.Both green algae (Chlorophyta) and other members of the plant kingdom share with the bryophytes the presence of chlorophylls a and b, xanthophyll and carotene, storage of photosynthate as true starch in plastids, sperm with whiplash flagella, and cellulose cell walls. Bryophytes differ from tracheophytes in having a dominant gametophyte supporting a parasitic sporophyte. They lack meristematic tissue, lignin, tracheid's (but have hydroids with similar function), and sieve cells (moss leptoids are similar function). The expected consequences of lack of lignin are not only small stature, but also lack of tracheid's and vessels, hence the term non-tracheophytes (Glime, 2007). Some have a cuticle, some absorb water directly through leaf surfaces. They do not have true roots. They instead have multicelled, root like appendages called "rhizoids," which anchor the plants and take in water and minerals. Because rhizoids are less efficient than roots, mosses generally prefer damp places with low light. When dry, they became dormant, drawing moisture and nutrients from the green portion of the plant back in the rhizoids, which causes their leaf like structures to curl. When moist conditions return, they spring back to life, turn green and grow. Their spores grow in beaklike capsules and are usually dispersed by the wind. Because of mosses acute sensitivity to pollution, they are potential indicators of the health of natural areas.

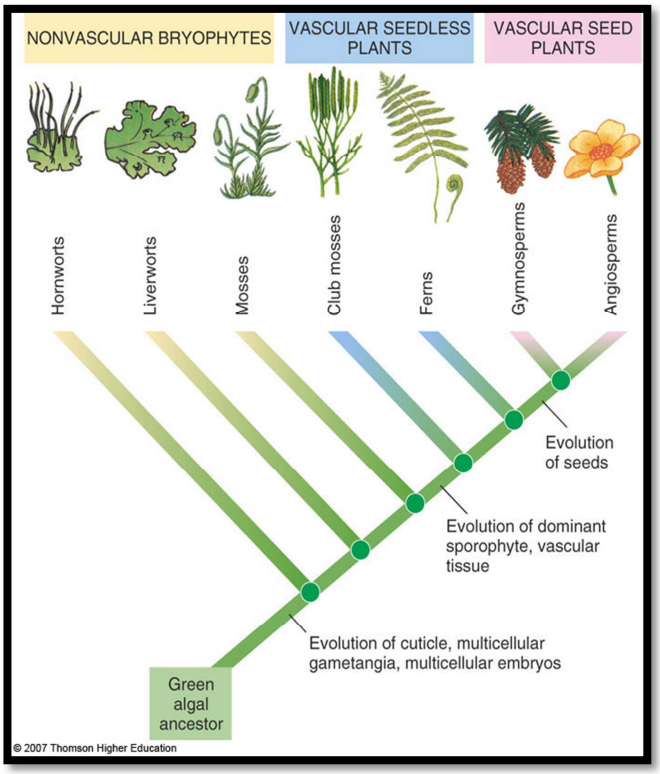
Most require moist environments to reproduce. All are Gametophyte dominant; Spend most of their life cycle in the gametophyte stage.

### 1.1. The Bryophytes: mosses, liverworts and hornworts

The most direct ancestors of plants are the Charophytes "*stoneworts*". Plants are four main groups (Figure 1).

1. Bryophytes – Nonvascular; spores
   - ● Mosses ● Stoneworts ● Liverworts
2. Seedless vascular plants; spores
   - ● Club Mosses ● Ferns, whisk ferns, and horsetails
3. Gymnosperms; seeds
   - ● Conifers ● Cycads ● Ginkgoes ● Gnetophytes
4. Angiosperms "Flowering plants"; seeds
   - ● Monocots ●Eudicots

**Figure 1.** Evaluation of land plants




Bryophytes are consisting of mosses, liverworts and hornworts (Figure 2). All are Gametophyte dominant and spend most of their life cycle in the gametophyte stage.

**Figure 2.** Hornworts (a), liverworts (b) and mosses (c)


Bryophytes have two stages in the lifecycle; Gametophyte – the dominant haploid stage in the life cycle, usually associated with mycorrhizal fungi. These have gametes.

Sporophyte – the short-lived, unbranched diploid stage in the life cycle of the Bryophytes. It contains a terminal sporangium,which produces spores that explode from the sporophyte, (known as a calyptra). This sporophyte releases spores which grow into protonema that develop into new gametophytes (Figure 3).

### 1.2.Hornworts (Anthocerotophyta)

They are most likely among the earliest land plants, yet the earliest hornwort fossil spores date from the Cretaceous period, 65 to 145 million years ago, when angiosperms were emerging.

The sporophyte is shaped like a tapered horn. The sporophyte has an intercalary meristem, so can grow indeterminately. The thallus has stoma-like structures, the only known occurrence in a gametophyte (Figure 3a-b). Each photosynthetic cell contains a single chloroplast. Archegonia are embedded in the thallus and in contact with surrounding vegetative cells. Cavities are filled with mucilage containing *Nostoc* sp. *Nostoc* provides a source of organic nitrogen which enables hornworts to grow on poor soils. Hornworts may be found worldwide, though they tend to grow only in places that are damp or humid. Some species grow in large numbers as tiny weeds in the soil of gardens and cultivated fields.

**Figure 3.** Hornworts


### 1.3.Liverworts

Liverworts were named in medieval times during the era of human discovery. Since they were lobed they were thought to be similar to the human liver. Liverworts are a group of non-vascular plants similar to mosses. They are far different to most plants we generally think about because they do not produce seeds, flowers, fruit or wood, and even lack vascular tissue. Instead of seeds, liverworts produce spores for reproduction. They always have unicellular rhizoids. Rhizoids are single celled. They have photosynthetic upper sides and non-photosynthetic undersides. Liverworts lack conducting elements, a cuticle and stomata. Their sporangia are often unstalked. They shed spores from the sporangia. Sporophytes without stomata, but have pores. Sporangium with dehiscent capsule, elaters present in some to disperse spores. They reproduce asexually using gemmules or ‘splash cups’, that survive as the “older” plant dies off.

Gametophytes are thalloid or leafy. Simplest of all living plants. Most cells contain numerous chloroplasts. Their habitat is moist, some aquatic, temperate and tropical areas. There are 6,000 species. Examples- Marchantia and Riccia.

**Figure 4.** Liverworts (a; *Marchantia sp*., b; Gemma cups)


Many freshly collected liverworts have a pleasing aroma, which quickly disappears as oil bodies disintegrate. Possibly defending liverworts from herbivores, terpenoids (chemically diverse and found in 90 percent of liverworts) have potential medicinal value. Liverwort sporophytes mature while completely enclosed in the gametophyte (Goffinet and Shaw, 2009).

### 1.4.Mosses

Mosses have spread all around the world and are found in wet environments such as rainforests, wetlands and alpine ecosystems. They are also common in urban areas with a wet climate and often establish on driveways, sidewalks, brick walls and other man-made structures. Mosses require water to reproduce which is why they struggle to survive in drier climates.

Although mosses are very primitive plants, their life cycle is in many ways very similar to all other land plants in that they have an alternation of generations. All land plants have alternating generations where one generation (the gametophyte generation) has half the genetic material as the second generation (the sporophyte). The gametophyte is produced when spores released from the sporophyte establish and begin dividing. When gametophytes are covered in a thin film of water, sperm cells are able to travel from one gametophyte to another and fertilize an eggs. The fertilized egg then develops into the sporophyte, which will in turn produce spores. The gametophyte is the dominant generation and the sporophyte is only able to survive due to the water and nutrients provided by the gametophyte. This is the opposite of almost all other land plants (Figure 5)(https://www.google.com.tr/search?q=thomson+learning+2001). Mature sporophyte consists of: foot (point of attachment), seta (stalk) and capsule (spore case) (Figure 6).

**Figure 5.** Life cycle of Mosses

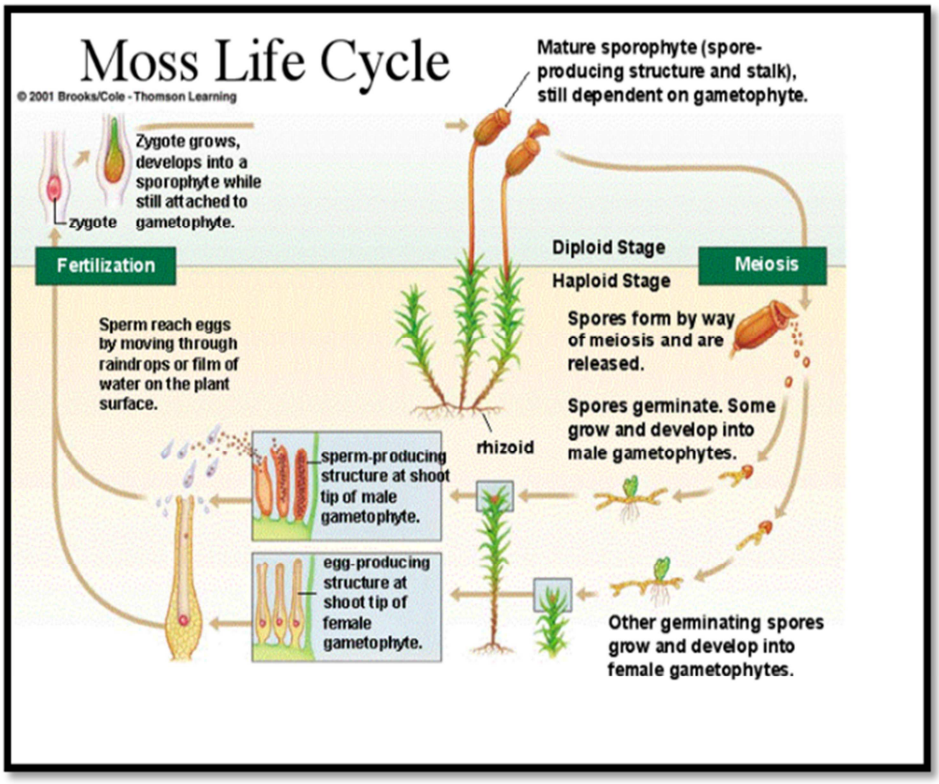
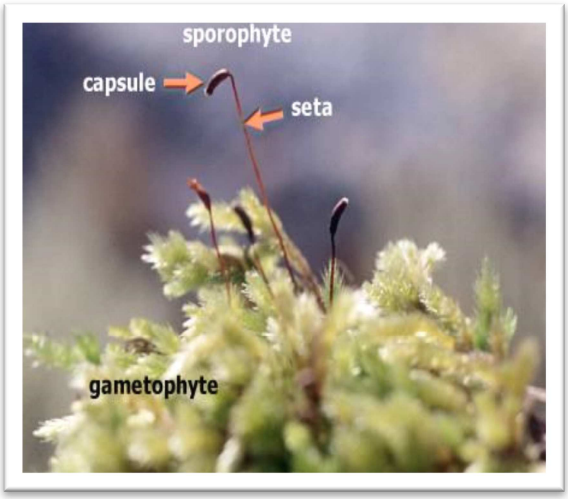



**Figure 6.** Mature sporophyte consists of: foot (point of attachment), seta (stalk) and capsule



## 2. ECOLOGICAL AND ECONOMIC BENEFITS OF BRYOPHYTES

Wind dispersal of lightweight spores has distributed bryophytes around the world. They are common and diverse in moist forests and wetlands.Some even inhabit extreme environments likemountaintops, sea-shores and deserts, except sea.

Bryophytes are important components of the vegetation in many regions of the world, constituting a major part of the biodiversity in moist forest, wetland, mountain and tundra ecosystems. Together, the three lineages, play a significant role in the global carbon budget and $CO_2$ exchange, plant succession, production and phyto-mass, nutrient cycling and water retention. Bryophyte communities offer microhabitats that are critical to the survival of a tremendous diversity of organisms such as single-celled eukaryotes, protozoa and numerous groups of invertebrates. These groups of plants are also important environmental indicators and have beenused as predictors of past climate change, to validate climate models and as potential indicators of global warming. Peat bogs are made mostly of moss called *Sphagnum*. They contain 400 billion tons of carbon and cut down the amount of greenhouse gases. Peat is harvested, dried, and used as a fuel.*Sphagnum* is harvested for use as a soil conditioner and plant packing material (Figure 7) (Glime, 2012).

One of the reasons for exploring biological compounds in bryophytes is the potential for medical use. Bryophytes contain numerous useful compounds, including oligosaccharides, polysaccharides, sugar alcohols, amino acids, fatty acids, aliphatic compounds, phenylquinones, and aromatic and phenolic substances (Pant & Tewari 1990).Bryophytes have been traditionally used for their medicinal properties in China and India.Native Americans have used them for drugs, fibers, and clothing. Bryophytes are used in biotechnological processes in quite a few cases but they have a huge potential. The active constituents of bryophytes are widely used as antibacterial, antifungal, cytotoxic, antitumor and insecticidal (Asakawa 2007) also in medicinal and agricultural areas (Saxena, 2004; Pant, 1998). Bryophyte are used as indicator species, erosion control, bioindicators of heavy metals in air pollution, aquatic bioindicators, radioactivity indicators, as material for seed beds, fuel, medicines and food sources, pesticides, nitrogen fixation, moss gardening, treatment of waste, construction, clothing, furnishing, packing, genetic engineering and for soil conditioning and culturing (Saxena, 2004; Glime 2012).Traditional uses of bryophytes include liver ailments, ringworm, heart problems, inflammation, fever, urinary and digestive problems, female problems, infections, lung disease and skin problems.

In aquaria, mosses not only are decorative, also provide oxygen, egg-laying substrates and hiding places (Benl, 1958).

**Figure 7.** *Sphagnum* packing material


**Figure 8.** Uses of Bryophytes in some biotechnological processes

### 1.1.Secret beauty of freshwater: Aquarium mosses

The aquatic mosses bryophytes are attractive, easy and beneficial plants. They play a vital role in regulating ecosystems because they provide an important buffer system for other plants, which live alongside and benefit from the water and nutrients that bryophytes collect. In aquaria, mosses not only are decorative, but provide oxygen, hiding places, and egg-laying substrates. Fish such as danios and killies will lay their eggs in the moss (Tinkerfish) (Glime 2012). Many mosses can be grown successfully in an aquarium. The limits may depend on the water quality, whether it is acid or alkaline, on the temperature, and on your ability to keep algae from taking over. includes the more common ones available in North America, Europe, and Asian areas (Benl 1958; Cook et al. 1974; Takaki et al. 1982; Gradstein et al. 2003; Tan et al. 2004; Tan 2006a; Glime 2012) (Table 1).

There are many different types of aquarium moss with a variety of different usages. This presentation contains information about eight types of most popular mosses. These species are Java moss (*Taxiphyllum barbieri),* Christmas moss (*Vesicularia montagnei),* Willow moss *(Fontinalis antipyretica),*Star moss (*Tortula ruralis*), Peacock moss

(*Taxiphyllum sp*.), Pellia moss (*Monosolenium tenerum*), Riccia moss (Crystalwort-*Riccia fluitans*), Phoenix moss (*Fissidens fontanus*).

**Table 1.** Suitable mosses for aquarium culture

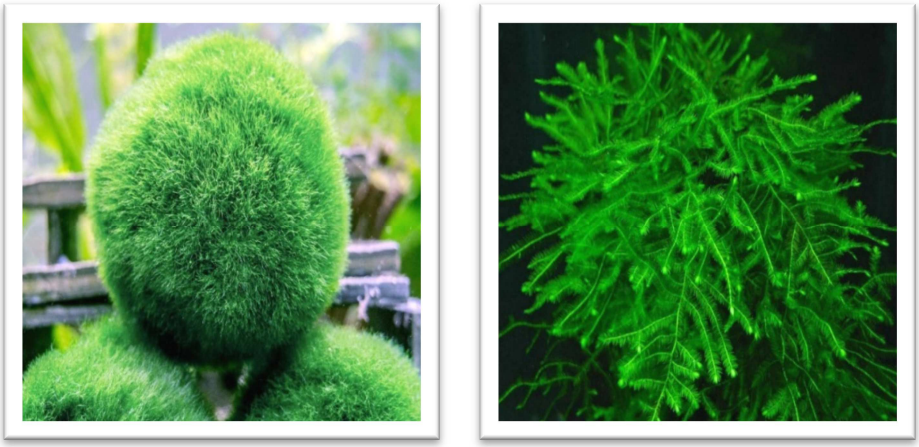
| **Scientific name** | **Common name** |
|---|---|
| *Amblystegium serpens* | nano moss |
| *Bryum pseudotriquetrum* | marsh bryum |
| *Chiloscyphus polyanthos* | square leaved liverwort |
| *Fissidens fontanus* | Phoenix moss |
| *Fontinalis antipyretica* | willow moss |
| *Glossadelphus zollingeri* | Bogor's moss |
| *Isopterygium sp*. | mini Taiwan moss |
| *Leptodictyum riparium* | stringy moss |
| *Monosolenium tenerum* | giant riccia |
| *Platyhypnidium riparioides* | beaked water moss |
| *Rhacopilum aristatum* | |
| *Riccia fluitans* | crystalwort |
| *Ricciocarpos natans* | water star |
| *Taxiphyllum alternans* | Taiwan moss |
| *Taxiphyllum barbieri* | Java moss |
| *Vesicularia dubyana* | Singapore moss |
| *Vesicularia ferriei* | weeping moss |
| *Vesicularia montagnei* | Christmas moss |
| *Vesicularia reticulata* | erect moss |
| *Vesicularia sp.* | creeping moss |

### 1.2.Java moss, Taxiphyllum barbieri

Java moss is one of the easiest plants to grow in an Aquascape, and it's a great plant for beginners to get their hands wet in the aquascaping world. Originating from Southeast Asia, Java moss is one of the most common aquarium mosses. Singh (2006) describes growing conditions as with or without fertilizer, with or without added $CO_2$, with or without added light, temperatures to 30ºC, and tap water. Loves moving water and if you don't attach it to rocks or wood, will attach itself to the tubing, a detrimental mistake. Not fussy about

light requirements, very versatile plant and growth is slow to moderate. In low light and lean water columns it may look smaller and thinner. It is often used as an egg-laying site for many fish, including the killifish and newly born livebearers (a small, chiefly freshwater, carp like American fish) can be protected and hide from their hungry parents and other small critters that live in the moss. You may fertilize it for faster growth, but it is not required because it pulls fish waste out of the water, resulting in cleaner water and self-fertilization. Java moss can survive growing fast andgreen in water conditions that would kill or brown most aquatic plants. It reproduces by dividing and spreading. Java moss grows best in medium light and it is hard to get rid of once you have gotten it started (http://www.aquaticplantcentral.com.

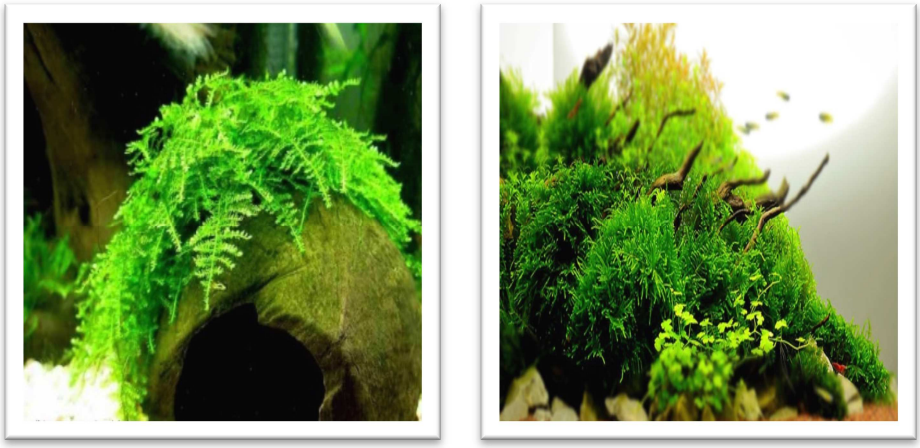
**Figure 9.** Java moss



### 1.3.Christmas moss, Vesicularia montagnei

Christmas Moss is very attractive and popular aquatic plant in the aquarium hobby which is also known as Xmas Moss. It is a creeping moss very widely spread in the tropical Asia including India, Japan, Philippines and Thailand.It is a very wonderful moss and is perfect for creating a moss backdrop or ground cover in the aquarium. It can grow up to 10 cm tall and its leaves are nearly round to broadly oval with an abruptly short and sharp pointed apex. The name for this moss is very indicative of growthstyle. Christmas is one of the most sought-after mosses, forming dense, bright green, irregular pinnate growth. Best temperature and pH are respectively 20-28°C and pH: 5.5-8. It is very popular among the aquarists for raising baby fish and tadpoles to protect them from cannibalistic adults. This moss provides habitat for tiny infusoria (class of one-celled organisms) which is an excellent source of food for both shrimp and fish fry. This plant is suitable for smaller or larger aquarium and it is completely free of algae and snails. The most common use of Christmas moss is to create a wall. It will slowly grow through the mesh, making a wall. It can be used as flooring as well, but it is not recommended because it will be easier to become an algae magnet this way and would be hard to keep clean to tank. Overall, Christmas Moss is an excellent plant for covering hardscape, filling in gaps and creating living environment in any aquarium (http://www.practicalfishkeeping.co.uk).

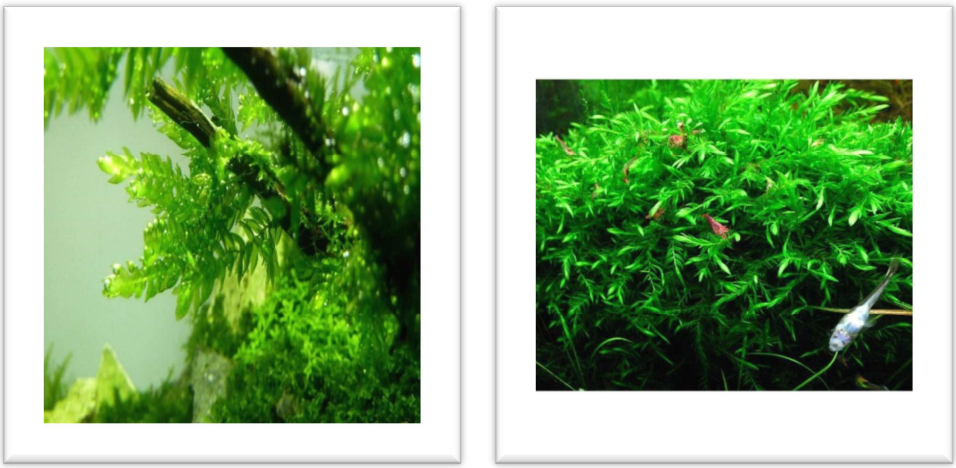
**Figure 10.** Christmas moss



### 1.4.Willow moss, Fontinalis antipyretica

Fontinalis antipyretica, commonly known as, is deep green in color and looks best as it grows larger and its vibrant light green tips begin to show. It gets its name from its resemblance to a weeping willow tree. It is originally from Asia, it has a slow growth rate with a height of 5-10 cm with medium light and carbon dioxide demand. It does well in lower temperatures and is very easy to grow and care for. It needs slightly brighter lighting, but may brown if the water becomes too warm. Also willow moss is great for most fish. Researchers found that the roach (Rutilus rutilus) spawned in thick beds of Fontinalis antipyretica, placing their eggs throught the fronds. This pretty native water moss makes a good slow-growing and easy oxygenator, but it is also an excellent habitat for wildife. Fish will spawn in its delicate bushy fronds, young amphibians and invertebrates hide in them. It grows attached to logs and stones (or in the garden pond, to the pond sides or plant pots), by means of creeping root-like structures, but it has no true roots and does not need to be potted. Good for shady areas of the pondand always keep the water clean and new, and keep the water flowing (http://www.theaquariumguide.com).

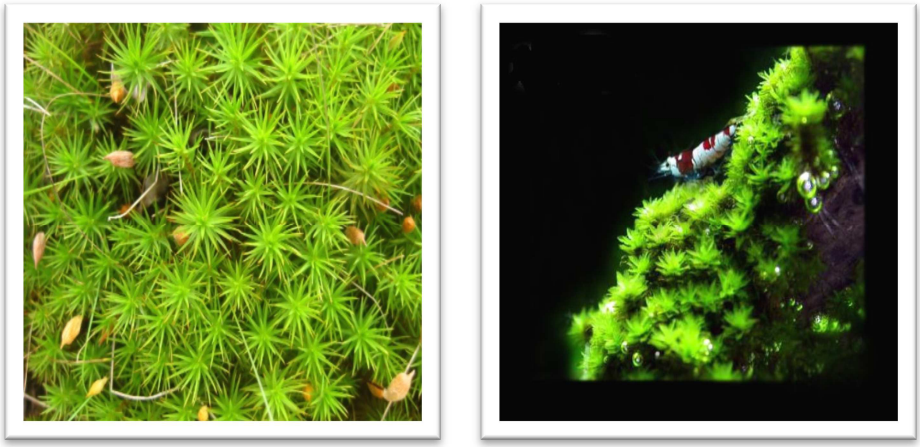
**Figure 11.** Willow moss



### 1.5.Star moss, Tortula ruralis

Star moss has a slow but easy growth rate. Although it is not a true aquatic plant, it can survive beautifully for about three months when submerged in a tank and can survive four months without water. It grows at 23-28 degrees Celsius with a pH level of 6.0 to 7.5 in low lighting. When grown in water, it has an appealing star-like structure, but only for a short time. It is best for a dry set up and loves places like desert. It occurs in North America, the Pacific, Europe, Asia, the Middle East, North and South Africa, South America, and Australia. It grows in many types of climate, including the Artic, boreal areas, temperate areas, and deserts. It grows in tundra, coniferous forest, grassland, sagebrush and other habitat types. This moss forms tufts of erect stems up to 4 cm tall. When it is wet it is bright green and the leaves are loose. When it dries the leaves wrap around the stem and it becomes reddish brown in color. It is dioecious. It also performs vegetative reproduction (http://www.theaquariumguide.com; http://www.efloras.org).

**Figure 12.** Star moss



### 1.6.Peacock moss, *Taxiphyllum sp.*

Another species of aquatic moss, which is very different from the other mosses such as Java moss, Christmas moss, or Taiwan moss. The moss has been identified to be belonging to the genus *Taxiphyllum*, which has a characteristic leaf cells that are narrowly oblong. This type of aquatic moss is a fern-like plant. It is creeping and small with flattened branches. These branches have fronds that spread out and are conspicuous because of their iridescent blue-green color. Peacock moss tends to prefer growing in cooler waters of around 25$^{o}$C. At higher temperatures, the moss starts to lose it peacock-shaped fronds. Peacock moss forms a creeping mat of feathery foliage. The stems of this plant may root into the ground near the tips, via the rhizophores, or branchless, root-like stems it produces on each stem. New plants can start from these. Peacock moss plants grow to about 15 cm tall, spreading 90 cm wide, but its stems are weak, which means they break easily. Peacock moss plants do not produce flowers. However, they do form cones, or strobili. Being from genus *Taxiphyllum*, it has more of a soft velvety texture than that of Christmas moss. It branches out very quickly from one single frond, spreading out as it grows like the fan of a peacock's tail (http://www.theaquariumguide.com).

**Figure 13.** Peacock moss

### 1.7.Pellia moss, Monosolenium tenerum

Pellia moss, is actually a liverwort, small, flowerless plants. It is an attractive addition to the tank. It is a floating plant but it tends to sink naturally as it grows larger. It's found where there' s high concentrations of nitrogen, usually in human locations, giving the plant access to excess agricultural fertilizers. When Pellia moss begins to thrive in the aquarium, it develops a green leaf-like structure almost 1 cm wide, which forks every 1 - 1.5 cm. The thallus is an attractive, slightly translucent olive green and flourishes in a wide temperature range, from 5°C to 30°C. It grows in shade or full sunlight and is tolerant of hard or soft water. It grows well under most water conditions and it is easy to maintain with low lighting and added carbon dioxide.It is heavier than water and therefore remains on the bottom. The Pellia moss is a popular hiding place for shrimp. Its appearance is similar to the Java, only much neater. It should either be attached to wood or stone, much like the other plants featured here, taking care not to break it up too much. When given optimal growing conditions and $CO_2$, small bubbles of oxygen can be seen on the undersides of the plant thallus (http://www.aquaticplantcentral.com; http://blueoptimism.tumblr.com).

**Figure 14.** Pellia moss

### 1.8.*Riccia* moss (Crystalwort), *Riccia fluitans*

There are more than 180 species of *Riccia*, many of them non aquatic. However, *R. fluitans* is a fully aquatic form, often seen floating in slack waters of a river or lodged in some crevices where there's rocks and wood. This form grows almost like another species. *Riccia* moss grows up to 5 cm tall. *Riccia fluitans* is actually a very easy plant to grow. Riccia's widespread distribution is due in part to its ability to tolerate a very wide range of environments, from medium soft to very hard water, pH ranges from 6.0-8.0 and temps from 15-30$^0$C. As a floating plant, moderate lighting is sufficient for good growth and $CO_2$ injection is unnecessary. It also appreciates rich fertilization through the water column, including nitrate, phosphate, potassium, and iron. When grown in good conditions, small oxygen bubbles will begin to form on the leaf tips. It normally floats, but can also be attached to underwater objects such as logs and rocks. It can be attached with plastic mesh. *Riccia* moss great protection and hiding for baby fish. This plant is also great for breeding tanks both to catch eggs and to protect fry (https://aquascaper.org).

**Figure 15.** Riccia moss


### 1.9.Phoenix moss, Fissidens fontanus

A newly 'discovered' aquatic moss, Fissidens fontanus which originates from USA, is now available in Singapore. It is a very nice Fissidens species and it is truly aquatic. The best part is that the rhizoids of Fissidens fontanus would cling on readily to the woods or stones after a while, and so doesn't require frequent re-tying of the moss. Fissidens is small in size and not very fast growing, one can see the potential of using Fissidens fontanus to cover the driftwood and bogwood and create a natural aquarium landscape. Like any other aquarium moss, phoenix moss can grow under a low level of light and with only little addition of nutrients and $CO_2$. Growth rate of this moss is quite slow in comparison with other mosses cultivated in the aquarium. A little injection of liquid fertilizer and $CO_2$, however, can accelerate the growth rate and helps to grow the lush mounds of Fissidens fontanus. The plant needs to grow bright green coloration is a lower temperature range, with 25°C being the optimum temperature and pH is 5-7.5. In higher temperatures, this plant will produce a darker green coloration and smaller fronds. Creating an aquascape, Fissidens fontanus is better to be

placed closer to the “focal points” and not in the corners of the aquarium, as it will definitely attract the viewer's attention even against the background of other mosses. Fissidens is a great plant for shrimp tanks, shrimp lets (baby shrimp) can hide in it and adults can too when it gets long, it naturally grows the micro fauna they forage on-shrimp are great to have in a Fissidens tank as they keep it clean (http://www.aquamoss.net; http://www.practicalfishkeeping.co.uk; http://aquascape-promotion.com).

**Figure 16.** Phoenix moss

### 3. CONCLUSION

Mosses in aquaria help to decorate while providing oxygen and hiding places, especially for laying eggs. They can be used to make walls, attached to logs and rocks, or grown from the sand on the floor of the aquarium (Figure 17-18).

Most aquatic bryophytes prefer cool temperatures, low nutrients, and medium light; more light encourages algal growth. Some animals like fish, snails, and algae shrimp may eat the mosses. A mesh wall can hold the mosses or they can be allowed to grow free. Algae can be removed with a weak bleach solution. Use of mosses as spawning grounds for commercial rearing of fish warrants further exploration.

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**Figure 17.** Arranged aquarium sample

**Figure 18.** Arranged aquarium sample