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Common Media Used in Hydroponics[1]

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Introduction

Hydroponics is a method of growing plants without using soil. In hydroponics, plants can be grown either directly in a nutrient solution (water-culture) or in an inert media (media-culture). In media-culture, the type of medium is critical to the success of plant production. Under normal growing conditions in the field, the soil provides plants access to some nutrients, as well as support and a place for plant roots to develop. In hydroponics systems, media can stabilize, providing a space for the roots to grow (Resh 2012). Media selection is an important consideration in hydroponic plant production. Designed for hydroponic beginners, this document will cover the basic properties of media and specifically discuss media commonly used in hydroponics.

Properties of Media

Like soil, different types of media will have different properties. When selecting media, different physical characteristics will offer some advantages and challenges. Ideally, media-based systems should use “inert” media materials that are chemically inactive, thus allowing all nutrients to be supplied through fertilizers added by the grower. Media selection depends on a few factors, including the types of plants being grown and the type of hydroponics system being used. Many physical properties of the media will affect the plants’ ability to take up nutrients and water. Some of these physical characteristics include pore space, water-holding capacity, aeration, cation exchange capacity and pH (Raviv et al. 2002). One great benefit of using media, compared to water-culture, is a larger margin of error with potential power surges or outages. This is because the media may hold some water for some time—without any media, plants without water will quickly decline. Some other major considerations of using media are the costs, both money and labor, to use and clean or replace media season after season.

Pore space is the space between the particles of the media. Pore space relates directly to *water-holding capacity* and *aeration*. Water-holding capacity is the volume of water the media can hold. Aeration is the volume of air the media can hold. The pore space is the area where liquid and air can be held, both of which are needed by the roots for plants to grow. More pore space means the media has higher water-holding capacity and aeration. Less pore space means that the media can hold less water and air. Larger-textured media will have bigger pores between the particles, allowing better drainage, but potentially reducing water-holding capacity. Plant roots need the correct ratio of air and water. The best media for hydroponics aims to have a desirable balance of water-holding capacity, aeration, and drainage.

Inert Media and Chemical Activity

In addition to water and air, plant roots take up nutrients. Roots absorb these nutrients as ions. For this reason, another important characteristic of soilless media is the *cation exchange capacity (CEC)*. This refers to the ability of the media to hold and release cations, which are positively charged ions. An ion is an atom or molecule with an electric charge resulting from the gain or loss of electrons. In most hydroponics, the nutrients are already supplied in ionic form mixed with water. The CEC will determine if the medium is able to hold nutrients. In hydroponics, media with no or low CEC is desirable so that nutrients are directly fed to the plants without chemically binding to the growing media. Many common media types have low CEC so nutrients are not stored in the media. When using media without CEC, all the nutrients are supplied through the nutrient solution. However, some media have a higher CEC and therefore can bind and store nutrients. Plants can sometimes access stored nutrients in the media, and these should be accounted for in fertilization programs. In other cases, the binding of nutrients to the media can make some nutrients unavailable to the plants.

Another important factor that will influence fertilization is the *pH* of the media, which is the measure of how many hydrogen (H) ions are in a solution. This can affect the availability of nutrients to the plant. When preparing your nutrient solution, you must adjust the pH of the solution to meet the needs of the plant. Most plants require a pH of around 5.5–7 to be able to take up nutrients. Certain plant species might prefer a different pH range. At higher and lower pH than the ideal range, plants might not be able to absorb nutrients, even if they are present. The pH of the media can influence the overall pH of the nutrient solution.

Media selection and hydroponics system selection go hand in hand. Not all hydroponics systems are well suited for utilization of media, while other systems require specific media so as not to compromise the system. For example, recirculating hydroponics systems must consider the risk of clogging of pumps and irrigation emitters and should not use fine or loose particle media.

Organic versus Inorganic Media

Media are considered organic if their components are carbon-based, such as coco coir. These materials will start to decompose, or break down, over time. For the hydroponic producer, the carbon to nitrogen (C:N) ratio is important when using organic media (Arenas et al. 2022). A high C:N ratio, usually greater than 30:1 C:N, will create competition for nitrogen between plants and microorganisms breaking down the media. The nitrogen can be stolen from the nutrient solution by these microorganisms, and some is lost as a gas in the decomposition process of the media (Grunert et al. 2016). This can lead to plants experiencing nitrogen deficiency if nitrogen is not added to the nutrient solution. When using a media with a high C:N ratio, higher nitrogen fertilization may be required so that plants receive enough nitrogen.

Inorganic media, such as vermiculite or perlite, do not contain carbon (though constituents might be found in nature). Some inorganic media are still permitted for use in certified organic operations. For a certified organic operation, the term organic refers to the management practices like fertilization and pest control. For more information on organic crop protection, visit https://edis.ifas.ufl.edu/publication/CV118.

Commonly Used Media

Although there is a wide variety of media used for hydroponic systems, not all media are suitable for all plants and all hydroponic systems. Other factors to consider include the availability and cost of different media, which can change based on the market. Here, we discuss a few of the commonly used media including properties and considerations for their use. A summary is provided in Table 1.

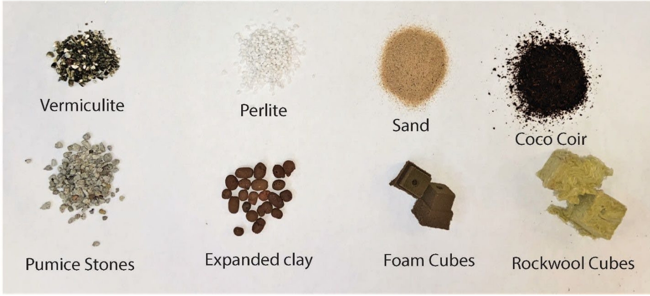

Figure 1. Several of the common media types used in hydroponics systems side-by-side. (Top, left to right: vermiculite, perlite, sand, coco coir; Bottom, left to right: pumice stones, expanded clay, foam cubes, rockwool cubes.)
Credit: Morgan Pinkerton, UF/IFAS

Coco coir is a coconut fiber made from the outer husk of coconuts. This material used to be considered a waste product, but now it is repurposed as a growing medium. It is one of many organic, carbon-containing, media. Coco coir is considered sustainable because it is renewable and easily composted. Coco coir can be sold as fine-textured or chunky products. Neither fine- nor chunky-textured coco coir should be used in recirculating hydroponics systems, because it can clog the equipment. The chunky-textured coco coir has more pore space, but better drainage and high aeration. Fine-textured coco coir also has a lot of pore space but with high water-holding capacity and good aeration (Raviv et al. 2002). In general, coco coir has a near-neutral to slightly acidic pH (5.5–6.8). It does have CEC and can hold on to nutrients like nitrogen, potassium, and phosphorus. This can impact the fertilization program. Additionally, coco coir should be washed or rinsed before use due to the high levels of salt that are common where coconuts are grown. Coco coir can be sold in several forms, such as loose media or compressed into mats, cells, or other shapes. Loose coco coir may be sold compacted and require soaking prior to media use. As plants grow, cubes can be stacked up to provide more space for the roots to develop.

Composted pine bark is made from the bark of pine trees. It is readily available in areas where there is active pine logging because it is a byproduct of the industry. The composting process makes this media useful in hydroponics, but only in certain hydroponic systems. Incompletely or inadequately composted pine bark may lead to increased competition for nitrogen due to high C:N ratios. Composted pine bark has a neutral to low pH around 6–7, which can decrease the pH of the nutrient solution. In general, composted pine bark has good water-holding capacity and pore space, and it has some CEC. It is sold in a wide variety of textures from fine to chunky, which can also depend on the degree of decomposition. As with coco coir, the chunky-textured pine bark has larger pore space with greater drainage and aeration. Composted pine bark, like other organic media, can break down quickly. Bark from other trees can also be composted and sold as hydroponic media. They have similar properties to composted pine bark and can be variable depending on the wood source. Hardwood sources often break down faster than pine bark and usually have a pH of 7 or higher.

Sawdust is made of finely ground wood and can be highly variable depending on the wood source. Some wood sources are not suitable for use in hydroponic systems as they contain toxins that harm plants. For example, sawdust from western red cedar (*Thuja plicata*) is toxic to plants. Sawdust has very high water-holding capacity, but it might have poor aeration and drainage depending on the texture. The pH can vary for different sources and tree species as seen with composted bark. It can have a little CEC. As with other organic media, it can break down over time and often decomposes faster than bark. Like composted pine bark, it is only used in certain hydroponic systems. Use of sawdust as a hydroponic media has declined in recent years since the introduction of media like rockwool (Resh 2012).

Peat is made from partially decomposed plants, including mosses, grasses, and sedges, that are removed from bogs. Sphagnum peat moss and Hypnum peat moss are two common types of peat. The quality of peat can vary greatly depending on the source and can even be different year to year from the same source. Peat generally has good water-holding capacity but does not hold water as well as coco coir. It has a lot of pore space and good drainage, but peat can be harder to rewet after drying than other types of organic media. The spongy nature of peat allows it to resist compaction. Depending on the source, peat usually has an acidic pH that might need to be amended with calcium carbonate to raise the pH. Peat also has CEC and can retain nutrients. Although slower than other organic materials, peat can further break down over time.

Rockwool is formed from rocks, specifically from aluminosilicates. The material is heated to high temperatures to form fibers, which are then made into blocks, cubes, or other shapes (Resh 2012). As with the coco coir cubes, rockwool shapes can be stacked as plant roots grow and develop. It has a neutral to slightly basic pH (7–8.5). Depending on the source, soaking to lower the pH may be required; this typically is included in instructions provided by the retailer. Rockwool has good aeration and high water-holding capacity. Unlike with coco coir, rockwool has no CEC. It is very lightweight when dry, though it can become heavy once wet. Although sterile prior to use, rockwool can be prone to algal growth and cannot be reused. Rockwool is not biodegradable, and disposal is often considered a major issue (Raviv et al. 2002).

Foam cubes, sometimes called grow foam, have similar properties to rockwool. The material is very similar to the foam used for flower arrangements. Like rockwool, foam cubes have high pore space with good aeration. Foam cubes have slightly better drainage than rockwool and are less prone to waterlogging. Additionally, foam cubes are not reusable, but depending on the manufacturer, are biodegradable or partially biodegradable, which helps with the disposal issue seen with rockwool. Foam cubes tend to fall apart over time, so they are not ideal for slow-growing crops.

Perlite is a material produced from siliceous volcanic rock, often from deposits in North America and the Mediterranean (Szmidt et al. 1988). The rock is heated and expanded. Perlite has high water-holding capacity and pore space. The high pore space gives perlite high aeration and easy drainage. This medium has a neutral pH and no CEC. It is very lightweight and sterile prior to use. Perlite does not break down, but it can be broken into smaller pieces during handling. It can also produce dust that can cause respiratory issues. Especially when handling large quantities, masks are recommended. Often, perlite is used in combination with other media for growing plants.

Sand is one of the oldest types of hydroponic media. Sand is a component found in soil in varying amounts. Florida's soils contains higher amounts of sand, but it also contains clay and silt. Pure sand, without clay and silt, can be used as a hydroponics medium. Sand is inexpensive by itself, but due to its weight, it can have a high shipping cost. Sand has a lot of pore space with low water-holding capacity and little to no CEC. The size of the particles can vary, and the ideal size used in hydroponics is between 0.6 to 2.5 mm in diameter (Raviv et al. 2002). Sand is often used in combination with other media to add weight and improve drainage. Depending on how it was sourced, sand can be contaminated with clay, which can cause problems in production.

Gravel and pebbles, like sand, were used as an early hydroponic media, such as during World War II. Larger than sand particles, the size of gravel and pebbles ranges from 5 to 15 mm in diameter (Resh 2012). They are very heavy, like sand, and provide good aeration and drainage. Their water-holding capacity and CEC are low. Gravel and pebbles are commonly used in ebb-and-flow and aquaponics systems. Calcareous gravel, which comes from limestone, should be avoided because it can release calcium carbonate and affect the pH of the nutrient solution. Gravel and pebbles may require sterilization prior to use and can be reused if properly sterilized.

Pumice stones are similar to perlite, despite the word "stone." They are made from crushed volcanic rock. Pumice stones are lightweight and have no CEC. This material has excellent aeration and good water retention. The water-holding capacity is higher than sand but lower than rockwool, perlite or coco coir. Pumice stones are cheap and easy to purchase but not often used because of their extremely low weight. They are most commonly used in aquaponics systems. When pumice stones are used, a mixture of large and small particles is needed (0.3 to 5 cm) to ensure proper drainage (Raviv et al. 2002).

Expanded clay, or "grow rocks," are made from clay that is heated to very high temperatures. This product is artificial and comes in a wide range of sizes (1 to 18 mm). The desired size depends on the level of aeration needed. It has very low water-holding capacity, so it might require more frequent watering cycles. This medium has high CEC and can store nutrients and salts. Expanded clay can be washed, sterilized and reused, making it fairly sustainable. One drawback is that it is very expensive, so it is mostly used by hobbyists and not commercial producers (Raviv et al. 2002).

Vermiculite is made from a naturally layered silica that has been expanded and heated. It can be purchased in various grades, which range in the size of the particles from fine dusts to coarse pellets. It is lightweight and porous, and it provides good water-holding capacity. The fine, lightweight qualities make vermiculite a common addition to germination media. It has a near-neutral pH (7–7.5) and low CEC. Magnesium is often adsorbed by this medium, which can be problematic for nutrient management. Additionally, if the pH is low, vermiculite can release aluminum into the solution, which is toxic to plants (Raviv et al. 2002). As with perlite, fine vermiculite can produce dust that is irritating to inhale.

Rice hulls are a by-product of rice milling and are used as a hydroponic growing amendment, which is typically mixed with other substrates like coco coir or peat and can increase aeration and drainage.

Soilless growing media or *potting media* are a blend of different types of growing substrates mixed at different rates. The media lack soil and typically include coco, peat, composted pine bark, perlite, or vermiculite. The proportions of each material coincide with customized water-holding capacity, drainage, and aeration requirements, which can be customized for specific crops.

Media Reuse

Hydroponic systems rely heavily on sanitation to prevent the spread of pests and pathogens. Some media are reusable with proper care. Other media will lose structure or degrade over time like most organic media and foam cubes. Some media might not degrade quickly, but they are not appropriate for reuse because they cannot be properly sterilized.

Sand, gravel and pebbles, pumice stones, and expanded clay are examples of reusable media. Media can hold on to pathogens from previous crops and harm new plants in subsequent plantings. It is important to start each planting with a clean system to prevent future problems. Media are primarily sterilized for reuse by either steam or chemical sterilization (Resh 2012). In steam sterilization, the medium is steamed at a high temperature (above 180°F) for a specific length of time to kill pathogens. This can require special equipment for proper sterilization, and the utility might depend on the type of hydroponic system. Chemical sterilization, such as bleach, is an alternative to steam sterilization. This process can be hazardous because many of the chemicals used are toxic to humans.

Conclusion

Media selection is an important consideration for hydroponic producers. In media-culture, the media can provide stability for plants to grow and the type used determines key properties like water-holding capacity and aeration. Although there are many types of media available, all have different properties and considerations that can influence their use in growing different plants in different hydroponic systems.

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Table 1. Summary of several physical properties of hydroponic media.

Media Type	Organic/ Inorganic?	Cation Exchange Capacity (CEC)	pH	Water-Holding Capacity	Aeration	Reusable Y/N?
Coco coir	Organic	Moderate	Slightly acidic	High	Good	N
Composted pine bark	Organic	Moderate to low	Slightly acidic to neutral	High	Good	N
Expanded clay	Inorganic	High	Neutral	Low	Good	Y
Foam cubes	Organic	None	Neutral	High	Good	N
Gravel and pebbles	Inorganic	Low	Variable	Low	Good	Y
Peat	Organic	Moderate	Slightly acidic	Moderate	Good	N
Perlite	Inorganic	None	Neutral	Moderate	Good	Y
Pumice stones	Inorganic	None	Neutral	Moderate	Good	Y
Rockwool	Inorganic	None	Slightly basic	High	Good to Fair	N
Sand	Inorganic	None	Neutral	Low	Good	Y
Sawdust	Organic	Moderate to low	Variable	High	Fair to Poor	N
Vermiculite	Inorganic	Low	Basic	Moderate	Good	Y

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