Greenhouse Horticulture

Greenhouses allow producers to grow year round, and typically yield 15 to 20 times more produce than an open field of the same area. Greenhouse horticulture is a dynamic, intensive system for food production, and it leads primary agriculture in both technological and resource management innovation.

Research and development in the BC greenhouse sector are currently centred on

- Consumer, retailer and cold chain expectations
- Regulatory environment
- Market projections for specific products
- Increasing crop specialization of grower/producers
- Changes in post harvest management practices
- Conceptual shifts in resource use and waste management models
- Available capacity of food processing / food manufacturing sectors
- Technological innovations in
  - Growing systems (nutrient/water/light delivery)
  - Harvesting practices
  - Biomass fuels and alternative energies
  - Soil-less media (substrate)

In addition to consolidating greenhouse production as a viable practice alongside traditional open field cultivation, the ongoing innovation and development in the sector is increasing the need for technical knowledge and skills among producers and their workforce.

Modern greenhouse production – especially hydroponic production, in which crops are grown in non-soil media called substrates – provides precise control of crop inputs and growing conditions, and an environment that is far more predictable than in open fields. The grower’s ability to regulate factors such as water and nutrient supply allows produce of uniform standard to be obtained at harvest and helps to project and control costs.

Hydroponically grown greenhouse vegetable crops require softer post harvest washing treatments than field grown produce. They are low in chemical residues, contamination and toxins as a result of the greenhouse environment:

- Absence of soil and weeds
- Use of sterile substrates (soil-less growing media) means there is no contact between edible parts of plant and soil borne contaminants
- Reduced use of over-head irrigation systems
3 Production Streams

BC’s greenhouse sector engages in three distinct types of production:

- **Vegetables** (tomatoes, cucumbers, peppers, lettuce, eggplants, herbs)
- **Floriculture** (cut flowers, flowering, potted, bedding and foliage plants)
- **Nursery** (trees, tree seedlings, shrubs, perennials and vines)

Vegetables

BC’s vegetable greenhouse growers employ about 3,800 people and gross almost $300 million annually. Greenhouse vegetable operations are in production for 10–12 months of the year, depending on the crop grown. The production cycle usually begins with seeding in October and most seedlings transplanted into the greenhouse in November or December. Some specialty operations may transplant as late as February or March.

Floriculture

Floricultural products are produced year-round, with products including cut flowers, flowering potted plants, bedding plants and foliage plants. BC floriculture includes wild harvested plants such as salal and fern.

Nursery

Nursery production includes the germination and growth of seedlings and the propagation of plants for use in Christmas tree, nursery and silviculture operations. This can include cultivation and propagation of wild-sourced plants.

Greenhouse Principal Buildings

The majority of BC greenhouse operations have an average area of 2-4 hectares (larger operations exceed 20 hectares in size). Principal farm buildings or structures in greenhouse production include:

- Greenhouse
- Header house
- Plant Nursery
Greenhouse Structure

The greenhouse structure provides a barrier to direct contact to the external environment and contains the internal controlled environment. The covering material allows for maximum light penetration for growing crops.

Gutter Connect Greenhouses

The basic greenhouse design in general use for vegetable production is a gutter connect greenhouse. These greenhouses are composed of a number of bays or compartments running side by side along the length of the greenhouse, typically 37 x 7.5 meters (120' x 25') in size. The production area between the bays is completely open, and the roof of the greenhouse consists of a number of arches, with each arch covering one bay and the arches connected at the gutters where one bay meets the next. This gutter connect design allows for easy expansion of the greenhouse when additions are planned. For instance, a single bay greenhouse of 240 m² (2,500 ft²) can be easily expand by the addition of more bays to cover an area of a hectare (2.5 acres) or more.

With a gutter connect greenhouse, the lowest part of the roof are the gutters, the points where the adjacent arches begin and end. Typical gutter heights for modern greenhouse structures are 4 m (13'), and the trend for future gutter height is moving to 5.5 meters (18'), with greenhouses becoming substantially taller. These taller greenhouses provide the grower with more options in crop handling, and provide a larger air mass per unit growing area. This is important because it is much easier to maintain an optimum growing environment within a large air mass than a smaller one.

There are a number of options for greenhouse covering materials: glass panels, polycarbonate panels, and polyethylene skins. Each of the coverings has advantages and disadvantages, based on the trade-off between cost, performance and length of service. Glass is more expensive, but will generally have a longer service life than either polycarbonate or polyethylene. The ability of the covering to allow light into the greenhouse and yet reduce the heat loss from the greenhouse to the environment is also important. New coverings are being developed which selectively exclude certain wavelengths of light and as a result can help in reducing insect and disease problems.

Since the southern coast of British Columbia has a mild climate, BC growers generally use greenhouses constructed out of single panes of glass, which allows for better light transmission. The greenhouse frame is constructed of aluminum and steel and is designed to let in the most light. BC Growers, in general, do not pave over the floor of the greenhouse, but instead lay down a thin plastic cover that prevents weed growth and is replaced every year, when new planting begins.
The Header House

The header house serves as a loading dock where produce is shipped and supplies are received. It also houses the greenhouse environmental control system, as well as the boiler, and the irrigation and fertilizer tanks. Staff lunchroom and washroom facilities are also generally located in the header house, placed so that they meet all food safety requirements with respect to the handling of produce. The header house is separated from the main greenhouse, with access gained through doors.

The Plant Nursery

The greenhouse will also include a plant nursery, if vegetable growers are committed to starting their own plants from seed. The nursery must be of sufficient size to supply transplants for the entire production area of the greenhouse, and built to provide a high degree of control, as young plants are extremely sensitive to their environment. Heated benches or floors are required, as is supplemental lighting. The nursery area may be used for production once the seedlings have been moved out.

Greenhouse Heating

The temperature needs of the type of crop being grown, the size of the greenhouse, outdoor winter temperatures and future plans for expansion all impact the work that a greenhouse heating system will be required to do.

Although the southern coast of B.C. has a mild climate, greenhouses still need heat on cooler summer days and during other seasons to ensure plants grow and thrive year round. Most BC growers use high efficiency natural gas powered boiler systems to heat their greenhouses and to maintain the region’s good air quality.

An adequately sized heating system is crucial for greenhouse production. The system must be able to maintain optimal temperatures on the coldest days of the year. Beyond the actual sizing of the system, and deciding what form of heating to use (forced air, boiler heat, or both) there is the issue of where the heat is to be applied:

- To the air, to support the plant canopy
- To the floor to influence the root system
- To the “plant head” to promote development of new growth

It can be difficult to provide optimum root zone temperatures during the coldest part of the year by only heating the air. Besides the difficulty in driving warm air down to the greenhouse floor, there is also the danger of bringing too much heat to the canopy in
order to optimize root zone temperatures. Conversely, floor heat (hot water, steam, oil or glycol systems) can easily maintain root zone temperatures, but cannot optimize air temperatures without providing excessive heat to roots. Heating systems, in addition to providing the optimum temperatures for crop growth and yield, are also employed in combination with controlled venting to dehumidify the greenhouse.

Heating the air and plant canopy

Natural gas furnaces are normally located at one end of the greenhouse and move the heated air down the length of the greenhouse to the far end. There are a number of types of forced air systems and all try to ensure that the heat is adequately distributed throughout the greenhouse to maintain the environmental air temperature set points. Boilers and pipe and fin systems can also be used to provide heat to the air. The main consideration for heating the air is uniform distribution of the heat throughout the entire greenhouse so that the entire plant canopy is equally affected.

Providing heat to the root zone

The most common system to provide heat to the floor or root zone is the "pipe and rail" system. A 5cm (2 inch) diameter steel pipe is placed on the floor between the rows of the crop so that the pipe runs down and returns along the same row approximately 45 cm (18 in) apart. Boilers deliver hot water through this heating pipe. The delivery and return pipe run parallel to one another, forming a "rail" that can be used by carts to run up and down the rows. The carts are useful when working with the plants during pruning and harvest. In this way the heating pipes serve a multiple use.

Providing heat to the plant head

"Plant head" is a term used by greenhouse vegetable growers to refer to the tops of the plant where the growing points are actively developing new shoot, leaves, flowers and young fruit. Some growers run hot water fin pipe 15 cm (6 in) above the head in order to obtain a more precise control of temperatures. This optimizes pollination of the flowers as well as early stages of fruit and leaf development. This pipe is raised as the crop grows.

Biomass Heating Systems

The ideal boiler burns a low cost, renewable fuel cleanly and efficiently, with minimal environmental impact. Although most BC greenhouses use natural gas, some growers have moved to high efficiency, clean burning wood, or biomass, boilers because of high and fluctuating natural gas prices.
Greenhouse heating is one of the highest operating costs for a greenhouse producer. Greenhouse heat is typically supplied by non-renewable fossil fuels, such as oil and natural gas. These fuels are also frequently used to enrich the greenhouse with carbon dioxide (CO$_2$) to enhance plant growth. However, the environmental impact and high cost of fossil fuels has led some greenhouse operators to look for alternative heat sources, such as biomass.

Biomass heating systems burn plant and wood waste to power central heating and hot water boilers. Biomass boilers can vary from 8 kilowatts up to multi-megawatt industrial power plants. Depending on their size, biomass boilers can be installed in the same way as conventional boilers. There are also biomass boilers that are suitable for installation directly within the buildings they heat, including decorative models that have the appearance of traditional stoves.

Biomass heating systems are far from a panacea. The initial capital investment required to install these systems can be challenging for small operations, and a substantial number of decisions have to be made to ensure the right technology is put in place.

Outdoor wood-fired boilers (OWBs) have increasingly gained in popularity with greenhouse growers who have ready access to a supply of cord and wood waste. Many of these units require no building or shelter, with heat outputs ranging from 100,000 to 1,000,000 British thermal units per hour. A new generation of cleaner-burning OWBs has entered the marketplace in the past decade. These OWBs meet the EPA’s voluntary lower emissions standards, emit up to 90% less particulate than non-compliant models, and offer significant increases in thermal efficiency.

GREENHOUSE BIOMASS BOILERS

A 14-acre floriculture producer in Vermont faced annual costs of $1 million when using oil to heat its operations. When the company made the decision to switch to biomass burners, its location in a heavily forested area made wood chips an obvious biomass fuel choice - cut costs and keep heating dollars local.

Six years on, woodchip biomass burners are heating the company’s extensive operations at an annual cost of $170,000, and the managers of this company, Pleasant View Floriculture, have the following advice for greenhouse operators considering biomass:

1. It’s not a flip of a switch
   Unlike oil or gas boilers, biomass systems need time for the fuel to burn, heat the water and become operational.

2. Transportation needs to be included in cost
   Biomass looks great when comparing wood chips to oil, but transportation costs need to be factored in.

3. Match furnace capacity to greenhouse size
   Run the numbers to see if it makes sense for the size of the greenhouse operation.

4. Investigate
   Don’t buy a biomass technology just because it worked for someone else. Visit operations running different biomass systems and request vendor site visits to determine what’s right for a specific greenhouse.

5. Get Skills, stock parts
   If the biomass boiler is purchased from a supplier outside of the region or country, it’s important that someone local understands how to repair the systems and that basic or crucial machine parts are kept in stock.

6. Over-maintain
   It’s critical to stay on top of boiler maintenance to ensure ongoing performance.
Biomass boilers and furnaces can be divided into two main groups: those that require manual stoking, or loading, and those with automatic stoking. Manually stoked boilers and furnaces are generally fueled by cordwood or waste wood, while automatic-stoking boilers and furnaces can handle a wide variety of biomass, including wood chips, wood pellets, biomass pellets and grains.

The best type of biofuel for greenhouse operations depends on availability and procurement cost. Scrap wood and old pallets often cost little or nothing and may require less labor and handling than cordwood, especially if the scrap is delivered. However, using scrap wood has potential disadvantages: possible chemical contamination or nails posing a hazard during cutting, handling and ash disposal.

Greenhouse producers who have access to low cost stands or sources of wood may still have to factor in labour and equipment costs. The average piece of wood destined for a boiler is handled 3-4 times before it is burned. In order to heat a 30 x 96-foot greenhouse from mid February to the end of May, a new generation OWB will burn 8 full cords of wood. For each cord burned, 4 to 6 tons of wood must be harvested and moved from the woodlot to the boiler. Despite these costs, wood may still be cheaper than other fuel options and may offer the advantage of providing employment for greenhouse workers during slower times of the year.

**Heat Storage**

A relatively new concept in greenhouse production is using water storage in combination with biomass heating systems. Biomass systems that burn fuels such as wood, coal and corn work most efficiently if operated at a constant fire rate. Adding a large, insulated water buffer tank can store excess heat generated during daytime operations to be used at night when heat demand is greater.

Water storage tanks with capacities of 1,000 to 500,000 gallons are available. They are usually made of steel with an interior liner or anti-rust coating, heavy insulation on the outside surrounded by a protective metal jacket. Smaller tanks can be delivered by transport truck. These storage systems allow producers to heat greenhouses using smaller boilers, as the water storage carries part of the overnight heating load.

Typical design looks at the maximum heat required for the coldest day. It also considers the maximum tank water temperature that can be achieved, the lowest water temperature that can be used and the storage period. Typical storage capacity is one gallon per 200 -300 Btu/hr of boiler heat capacity, with a storage...
period of 1 to 2 days. For small growers with a good wood supply an outdoor wood boiler may be a good alternate fuel source that will lower heating cost. Installing a 3,000 to 4,000 gallon insulated water tank can provide the buffer capacity needed to store excess heat for the night.

**Greenhouse Irrigation**

Greenhouse operators apply irrigation water daily in frequent, brief applications. Fertilizers are generally applied through the irrigation water. Recirculation systems are used whenever practical to collect excess irrigation water and to prevent leachates from entering groundwater. Many growers recycle their water and nutrients, pumping them back into the feeding system. Growers constantly monitor the watering and nutrient levels by computer, adjusting the amounts fed to the plants based on the amount of light in the greenhouse. Many greenhouse growers collect rainwater and pump it into their watering systems.

All irrigation systems consist of a set of basic components:

- **Pipes** transport water and nutrients. They are sized for the flow rate and distance the water is being carried so the pressure loss by friction is not excessive.
- **Pumps** move the water (gallons per minute) and bring it under pressure (pounds per square inch, psi).
- **Water meters** measure how much water has passed a given point in the system.
- **Valves** are used to turn on or off the flow of water in the pipeline. Manual valves are typically gate or ball valves that open fully to allow water to pass with a minimum of restriction. Electric solenoid valves use 24-volt electric to hold an internal valve open; a time clock controller is used to operate the valve.
- **Pressure regulators** act on moving water to maintain a given pressure.
- **Pressure relief valves** are designed to allow water to "blow off" to reduce pressure when sudden increases in pressure occur within the system. The diameter size does not necessarily relate to the pipeline size.
- **Backflow preventers** stop water from carrying contamination back to the source, i.e. a well. Backflow preventers must be installed to protect the water supply if chemicals are injected into the irrigation system. A basic backflow preventer has a check valve, an air vacuum breaker, and low pressure drain
  - A **check valve** is a one-way flow device that allows water to pass in one direction but that closes if water reverses direction.
  - An **air vacuum breaker** allows air to enter the pipeline when there is no water pressure and thus prevents a vacuum from being created to pull water pass a closed check valve. It also allows air to escape when a water pipeline is being filled with water.
A low-pressure drain valve opens when the system pressure is very low to allow water to drain out. It is used to drain any remaining water in a pipeline after the system is stopped or to drain any leakage past a check valve.

Fertilizer injection systems deliver dissolved or liquid fertilizer into the irrigation system when the water is flowing. Sometimes other chemicals are injected to control other water quality situations.

- Electrical conductivity meters (EC) and pH meters may be desired beyond the injection site to monitor the nutrient levels in the irrigation water.

The primary models for greenhouse irrigation systems are the overhead sprinkler system and the micro-irrigation system. Each system addresses specific plant production and water supply situations, and performs very differently in terms of:

- Water application patterns
- Efficiency of delivery
- Application uniformity
- Operating conditions
- Requirements for clean water

Overhead Sprinkler System

Overhead sprinklers spray water into the air above and around the foliage of the crop in a broadcast pattern. Overhead sprinklers include fixed installations, center pivots, traveling guns, and portable sprinklers. Each overhead system has its own design characteristics:

- Discharge rates range from ½ gallon to 1,000 gallons per minute, with wetting diameters ranging from 35 to 300 feet.
- Application rate (the penetration of water into the soil) is measured in inches per hour (IPH). 0.2 to 0.5 IPH is standard for sprinkler systems.
- The circular pattern of application makes it difficult to achieve a high degree of uniformity in delivering water to all plants.
- Sprinkler irrigation is 70% efficient in water delivery, with evaporation occurring in the air, from the plant foliage, and from the ground surface.
- It is a challenge to try to match sprinklers to a small or narrow area. Over-irrigation often occurs (i.e. the duration of the watering is too long) since plants on the fringes have to be adequately wet.
Micro-Irrigation Systems

Micro-irrigation systems include all small emission devices (individual emitters, row crop tubing, spray strakes, micro-sprinklers, etc.). All of these devices are designed to distribute water to small, discrete areas – specific beds or even individual plants. These systems have very small openings, called emitters, that discharge water in a drip or trickle manner. Because of their targeted delivery of water and low flow rates, micro-irrigation systems have become synonymous with cost efficiencies, water and energy conservation, and cutting edge technology. Micro-irrigation systems have been demonstrated to be 90-95% efficient in water delivery.

Comparison of the Two Systems

The majority of BC greenhouse producers water and feed their plants using micro-irrigation irrigation systems. These systems require more advance planning and labour than overhead sprinkler systems, and also have additional operating and maintenance requirements. For example: periodic chlorine injections are needed to keep the system free of algae or bacterial slime; acid injections, along with periodic system flushes, may be necessary to remove mineral build up.

However, micro-irrigation systems have been shown to use from 4,000 to 10,000 gallons of water (versus up to 36,000 gallons for an overhead sprinkler system) to deliver 1 inch of water into the soil over one acre. This is a remarkable savings in water use. The pumping station and pipe size requirements are also smaller for a micro-irrigation system than for overhead sprinklers.

Lighting

The natural light level in BC’s southern coast is too low for vegetable plants to grow year round. Supplemental lighting is essential to greenhouse crop production. Some BC growers are testing artificial lights for year round vegetable production. Screens that keep light inside the greenhouse are available. However, some vegetable crops are very sensitive to the heat that builds up if these screens completely enclose the greenhouse: vegetable crops can die from being overheated. Researchers are working to develop screens that “breathe,” allowing heat to escape and the plants to thrive.
Pesticides / Herbicides

The greenhouse industry in BC is considered a world leader in the use of biological control technologies. Because they use substrates for growing rather than soils BC Greenhouse operations require no herbicides and little or no pesticides. A plastic sheet, which suppresses weeds from growing up through crops, covers the soil in greenhouses. At the end of each growing season, the plastic sheet is removed to allow for a proper cleaning of the greenhouse facility. This cleaning ensures no pests or plant diseases from the previous crop are carried into the next growing season. Over the growing season, greenhouse producers introduce predatory insects – like ladybugs and mites – to eliminate harmful pests. In the rare situations where pesticide use is necessary, care in application rates and storage techniques are taken.

Greenhouse Wastes

Greenhouse wastes such as crop residue, plastics and growing media must be handled, collected, stored, and disposed of in accordance with the Agricultural Waste Control Regulation.

Removal Of Soil Or Placement Of Fill

Soil removal or placement of fill is a permitted agricultural activity in situations where this practice is necessary. A Notice of Intent must be submitted to the Agricultural Land Commission for specified farm and non–farm uses where soil or fill must be removed or introduced. Allowable specified uses include greenhouses and composting facilities. Proposals under the Notice of Intent require approval of the Land Commission.

Wastewater Management

Storm water runoff from greenhouse operations is permitted to enter municipal drainage systems, provided that a storm water management plan has been prepared in accordance with municipal bylaws. Water containing nutrients or other agricultural waste must not be directly discharged into a watercourse or groundwater supply.

Wood Waste

Many greenhouse producers use wood waste as a fuel source in biomass boilers.
Carbon Dioxide

Carbon dioxide (CO₂) is one of the by-products of the combustion of fuels that power greenhouse boilers, and is also one of the major elements plants require for photosynthesis and growth. CO₂ promotes stronger plant cell development, increases fruit set (the stage in which the plant’s flowers are fertilized) and enhances fruit production. Capturing CO₂ from the flue gases and distributing it in the greenhouse costs very little. Producers deliver CO₂ to greenhouse plants through thin plastic tubes that run along the base of the plants’ stems.

BC INNOVATION
Turning Carbon Dioxide into Food

In 2012 a BC greenhouse grower and a Dutch energy company launched a new carbon-capture-and-storage technology that transforms carbon contained in biomass into food.

SunSelect Produce Inc. and Procede BV’s carbon-capture-and-storage system was the first commercial operation of its kind - in the world - to convert the carbon in biomass into fertilizer for food. The technology heats greenhouse operations with low-cost biomass fuels, and filters emissions to capture the carbon dioxide and feed it to the growing plants as a natural air-borne fertilizer. The system removes five tonnes of carbon an hour from the facility’s biomass burner, and recycles it for the carbon-hungry crops that SunSelect grows. SunSelect switched from natural gas to biomass as a source of heat for its greenhouse several years ago when natural gas prices spiked.

The technology uses a patented organic liquid to remove the CO₂ from the exhaust of the greenhouse biomass burner. The liquid is then heated, releasing the pure CO₂ into the greenhouse for the plants to use.

The innovative carbon-capture-and-storage system cost $5 million to develop. The joint venture partners received $2.24 million from the British Columbia Innovative Clean Energy Fund and $1.72 million from Sustainable Development Technology Canada. A critical element in the success of the program was the replacement of natural gas (a fossil fuel) with biomass fuels (a renewable energy source). This allowed SunSelect to sell carbon credits through Offsetters, a B.C. organization that certifies greenhouse gas emission reductions by businesses, and buys and sells the resulting credits on B.C.’s carbon market. That sale offset 10% of the capital costs of the equipment and it’s revenue that continues to come in every year.

Here’s how Victor Krahn, CEO of ProSelect Gas Treating, describes this greenhouse carbon capture and storage technology: “We are taking the carbon dioxide, and instead of letting it go into the atmosphere, we are converting it to food. We are eating our way to a carbon-negative future.”
Greenhouse Substrates (Growing Mediums)

Most BC greenhouse producers grow food hydroponically. Although there is no soil in a hydroponic system, a solid, non-soil growing media or substrate is used. A substrate is a blend of organic and inorganic materials that provides the conditions needed for plant growth:

- Holds water
- Holds nutrients
- Permits gas exchange to and from roots
- Anchors plants

The ideal substrate:
- Drains well
- Holds water
- Holds nutrients
- Reduces nutrient leaching
- Has a low carbon to nitrogen ratio
- Has an ideal pH that can be adjusted
- Suppresses disease
- Does not accumulate salts
- Is inexpensive
- Is readily (preferably locally) available
- Is ultra lightweight, with low bulk density
- Facilitates plant establishment in the landscape
- Produces vigorous plants

In order to grow, plants require air, water and nutrients at their roots. The physical properties of a substrate determine how much air and water it can hold, how easily roots can expand within it and also the degree of physical support it provides to the plant as it grows. The substrate’s chemical properties determine how it holds and transports nutrients to the plant’s root system.

Physical Properties

All substrates are a combination of solid particles and space, and each substrate has its own characteristics, determined by the size, shapes and textures of the particles in it. Texture refers to the size of the substrate particles and their relative quantity. Structure describes how those particles are bound together in aggregates or compacted by handling.
PORE SPACE

Pore Space refers to the spaces between and within the individual particles in a substrate – called macropores. Macropore shape and size affects how a substrate holds water and air. If macropores in a substrate are too small, too much water is held and very little air is captured. If macropores are large, very little water is retained. A substrate with a wide range of pore sizes will hold water and air in nearly equal amounts.

POROSITY

The total space in a substrate that can be filled with either air or water is called its porosity. A hydroponic substrate should have a porosity of roughly 70% of its total volume. The porosity of a substrate – the extent to which it holds water and contains air – helps growers to calculate how much water and nutrients they need to give to a crop.

• Water Holding Capacity (WHC)
  The WHC of a substrate should be 30-60% of its total volume.

• Air-filled Porosity (AFP)
  The air-filled porosity (AFP) of a substrate is the volume of air it contains after having been heavily water and allowed to drain. The AFP for a substrate should be 10-30% of its total volume. If the substrate is too dense, and there is not enough air space, plant roots are suffocated. They become inefficient at absorbing nutrients, growth slows and root disease can rapidly take hold.

UNIFORMITY

Uniformity of substrate material can have a significant impact on crop production. If there are variations in the greenhouse substrate it becomes difficult to manage the irrigation and nutrition of the crop. Uniformity of organic substrates will naturally decline over time, as they decompose and plant roots fill air spaces. These changes affect substrate performance (e.g., by the end of a crop cycle the substrate may hold more water and less air, increasing potential for disease) and require adjustments to management strategies (e.g. changes in volume and frequency of irrigation). Because inorganic substrates are typically consistently uniform they make crop management easier and are attractive to growers for this reason.
EVEN WETTING

To maximize crop production, substrates have to wet evenly and appropriately for the crop grown. For instance, if the substrate drains quickly, the water and nutrient solution needs to be applied slowly, over a longer period of time, in order to reach plant roots rather than simply be washed away.

Chemical Properties

Unlike soil, substrates do not supply the nutrients needed by the plant. Nutrients are applied in controlled, balanced amounts. Some organic substrates can interact with nutrients and render them unavailable to the plant while other release unwanted trace elements into the nutrient bath. If the nutrient solution is not adjusted to compensate for the substrate’s chemical properties, it can lead to serious problems for the crop.

CATION EXCHANGE CAPACITY (CEC)

The CEC of a substrate is a measure of how readily it holds and releases nutrients required for the plant’s growth. Substrates with high CEC have a nutrient buffering effect (they hold nutrients well and resist having them flushed away) that reduces the risk of over-fertilizing, but also reduces a grower’s ability to use nutrition to manipulate plant growth. Substrates with low CEC (known as “inert”) give growers greater control over plant growth patterns.

pH BUFFERING CAPACITY

pH describes the degree of acidity in a material. The optimum pH for a soil or substrate (the level of acidity that allows a plant to readily extract available nutrients) is generally in the range of 6.5 (roughly the same pH as milk). Strong pH buffering capacity of a substrate indicates how readily or easily its pH can be adjusted to provide optimum pH conditions for a crop. Organic material has a high pH buffering capacity, so greater amounts of acid or base must be added to it to change its pH than are required for inorganic materials, which have low pH buffering.

Leading BC Greenhouse Substrates

The material used in BC greenhouse substrates can be classified as:

- Natural or synthetic
- Biodegradable or non-biodegradable (organic or inorganic)
- Renewable or non-renewable
Rockwool
Synthetic, non-biodegradable, renewable
Rockwool, used widely in BC greenhouses, is made from Basalt rock and chalk, melted together and blown into fibres, giving the product its distinctive name and appearance: like wool spun from rock. Rockwool has excellent water and oxygen holding capacity and sustains the roots of almost any plant. It’s available in multiple sizes and shapes, accommodating a range of grower needs. Rockwool is inorganic and not biodegradable. A dust mask, goggles, and gloves must be worn when handling it. Rockwool is much more alkaline than other media, so special adjustments to plant nutrient solutions is needed to create ideal pH for the root zone.

Coconut Fibre (Coir, Cocopeat)
Natural, biodegradable, renewable
After a decade of trial and development, coconut fibre has become a mainstream growing media, available in a variety of formats and dimensions, and rapidly becoming one of the most popular growing mediums in the world. Made from waste products of the coconut industry: the pulverized, composted, dehydrated, compressed and rehydrated husks of coconut shells, processed over a 2 year period. Coconut fibre is regarded as an extremely high performance medium in hydroponic systems, with a large oxygen capacity and a superior water holding ability. Coconut fibre is also high in root stimulating hormones and offers some protection against plant root diseases, including fungus infestation. The extensive processing affects the longevity of the fibre and the duration of its use as a substrate. Growers must also be careful when purchasing coconut fibre. There is a commonly available, lower grade of coconut fibre that is high in sea-salt and very fine-grained and performs poorly in hydroponic systems.

Peat
Natural, biodegradable, non-renewable
Peat is an organic, sedentary deposit that consists predominantly of dead plant material that has not completely decomposed completely due to a lack of oxygen. Stable, lightweight, with high CEC and organic content and low pH, peat is the medium most extensively used in hydroponic substrates. Unfortunately the use of peat in both nursery and horticultural production is causing a gradual depletion of peat bogs worldwide, and the recovery of these bogs is very slow. This has caused the price of peat to rise, encouraging suppliers and growers to seek alternatives.
Sawdust
Natural, biodegradable, renewable
Sawdust has poor nutrient uptake and water holding capacity when used on its own. Often used as a bulking agent, to improve substrate air holding capacity and provide structural support to plants. Sawdust should be completely composted before use. Has high carbon to nitrogen ratio, additional nitrogen needed in nutrient cycle.

Pine Bark
Natural, biodegradable, renewable
• Increases air porosity
• Acidic
• Resists decomposition
• Must be composted, with pieces less than 1/4” in size

Wood Fiber Substrate (whole tree)
Natural, biodegradable, renewable
• Must be composted, dried and finely ground
• Low CEC
• No pH buffering capacity - pH changes can occur rapidly

Sewage sludge
Natural, biodegradable, renewable
• High CEC
• High pH
• Possibility of heavy metals
• Can only be used for up to 10% of substrate media by volume as it is heavy and can negatively impact air holding capacity

Mushroom Compost
Natural, biodegradable, renewable
• High pH
• Potential high salt levels – must be tested and rejected if soluable salts high
• Can be used to make up to 50% of substrate by volume
• Will continue to decompose and increase in density while in substrate
Par-boiled Rice hulls
Natural, biodegradable, renewable
• Rice industry by-product
• Used to add porosity to substrate
• Can be used to make up to 30% of substrate by volume
• Neutral pH
• Low CEC

Sand & grit
Natural, non-biodegradable, renewable
• Good drainage
• Low water holding capacity
• Heavy

Calcined clay
Synthetic, biodegradable, renewable
• Clay, fuel ash, or shale that has been fired at high temperatures
• Low bulk density
• Internal porosity of 40 – 50%
• Reduces phosphorous leaching
• High CEC

Vermiculite
Synthetic, non-biodegradable, non-renewable
• Aluminum/magnesium/silicate blended and processed at 1000° C
• Expands 15 to 20 times when watered
• Larger the particle size the greater water holding and air holding influence
• High pH
• Possible asbestos contamination

Perlite
Synthetic, non-biodegradable, non-renewable
• Volcanic glass with high water content
• Ground and subjected to high heat (sterile)
• Chemically inert
• Resists compaction
• Enhances drainage
• Increases air-filled porosity
• Health risk - inhalation