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GREENHOUSE STRUCTURES

Greenhouse production is becoming increasingly popular throughout Nova Scotia. Some of the benefits associated with protected production include:

- Reduced incidence of plant disease resulting from rain water on plant parts
- Higher marketable yield compared to field grown systems
  - » Especially true around the tail ends of the growing season
- Less uncertainty regarding growing conditions
  - » More consistent yield from year to year
  - » less guess work around water supply by precipitation
- Extended growing season, with the potential for year-round production

There are a variety of greenhouse structures available for use. Desired crop, production time line, budget, degree of environmental control and the growing site will dictate which of these is most appropriate.

CATERPILLAR TUNNELS

Caterpillar tunnels are the most basic structure one can integrate into a production regime. They can be implemented as low tunnels or high tunnels and offer protection against temperature drops and precipitation that threaten the quality of the produce. The plastic is manually adjusted as needed throughout the day. Sides are lifted on warm sunny days to maximize light uptake from the plants and allow air to flow through the canopy and closed to protect the crop from the environment.

BENEFITS	DRAWBACKS
Relatively cheap (price per square foot)	**Labour intensive and time consuming** • Raising and lowering of the plastic to adapt to hourly/daily weather
Quick to install	**Limited when it comes to automation and technology**
Easily moved • Helps maintain quality growing soil	**Very little temperature control outside of plastic adjustment**
Extends the growing season • Earlier planting dates • Extended harvest at the end of the season	**Not ideal for year-round growing** • Lack of insulation at the base • Plastic tends to freeze, then tear in sub-zero temperatures

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LOW CATERPILLAR TUNNELS

Low-lying caterpillar tunnels, or low tunnels, are typically 2-3 feet above the soil line. The hoops used for these structures can be pushed into the ground or made up of a rebar and PVC pipe combination.

Crops Grown

- Greens
- Herbs
- Strawberries

Figure 1. Two images depicting a low tunnel system, with one side lowered to protect from the elements while leaving the other side exposed. Photo credit: Tunnel Berries, Marvin Pritts.

HIGH CATERPILLAR TUNNELS

Large caterpillar tunnels can get up to 14-16 feet wide, with the peak sitting over six feet above the soil line. The hoops used for large caterpillar tunnels are typically reinforced with rebar posts in the ground. While more permanent greenhouse structures would have steel/metal reinforced along the top (known as a purlin), caterpillar tunnels have a high-strength strap that runs from end to end which supports each hoop along the top of the structure. The presence/absence of end-walls, vent adjustment and configuration, and the plastic's attachment to the structure are some of the major differences between large caterpillar tunnels and hoop houses.

Figure 2. An image of a large caterpillar tunnel, with the end-to-end plastic typically seen in this style of tunnel. The structure's basic components are seen here – anchor which the end of the plastic is secured around, the hoops that support the plastic, the plastic itself, and the tie-down material used to hold the plastic against the metal frame. Photo credit: **https://multisheltersolutions.com/applications/hanley-caterpillar-greenhouses/**

Crops Grown

- Vine crops (tomatoes, peppers, eggplant)
- Leafy greens
- Herbs
- Other vegetables

Standard components of a caterpillar tunnel are:

1. **Hoops**
   These are typically made of steel, with a range of thicknesses. The thicker the hoop, the more stable it will be while still allowing for maximum sunlight on the crop. PVC is also commonly used and sits on two secured pieces of rebar that have been inserted into the ground along the sides of the beds. Hoops should be placed 5 feet apart to maintain the integrity of the plastic covering the system (less stretching and damage caused by water accumulation).

2. **Plastic**
   There are many different plastics on the market. A thinner plastic will be more prone to tears compared to a thicker plastic but allows for increased light passage. Some plastics come with perforation to help with airflow through the space, while others do not. The most suitable plastic will depend on the climate in the production space.

3. **Tie-down material**
   This is used to secure the plastic to the frame. Twine, bungee cords, or parachute cord are all viable options to keep the plastic in place.

4. **Anchor object**
   These are crucial pieces of the structure that secure the plastic on each end of the tunnel. Stakes, posts, or pipes typically hold up well – it is best to avoid a wood product here as they are much less durable. There are even options to rig up a ratchet system to assist with tightening the plastic as it stretches through the season.

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UMBRELLA STRUCTURE

Although not very common in Nova Scotia, umbrella-style tunnels are making an appearance in a handful of crops across Canada. These tunnels exist as a multi-bay system, meaning there are a series of these structures placed next to each other. This system results in a large area being protected from precipitation. The covering between bays is not continuous across the whole structure, so each bay only has partial coverage from above.

BENEFITS	DRAWBACKS
Relatively cheap compared to a high tunnel structure	**Does not offer season extension**
Offers protection from the elements • Higher marketable yield • Improved shelf life	**Does not hold up well under high winds** • Plastic must be removed for wind events or throughout the winter to protect the structure
Suitable for tall crops	**Limited in where they can be placed** • Not suitable for open/windy spaces

Crops Grown:

- Brambles (raspberries, blackberries)
- Could easily be employed for fruit trees and/or other crops

Figure 3. Two images of an umbrella structure installed over a long cane raspberry crop. Notice that the plastic is not continuous between each 'bay', offering the crop protection from the rain while still being quite open. Photo Credit: Beatrice Amyotte, AAFC.

STAND-ALONE HIGH TUNNELS

High tunnels come in a range of sizes. The standard high tunnel is usually 30 ft wide and 96 ft long, with peak heights that range from 7-15 ft., but this can be modified depending on the supplier and the building site.

Vents in the roof, side or end walls allow hot air to escape and create room for drier air to move through the canopy and remove moisture from the space. The ends of these structures can be open or closed, depending on the design and the goal of the structure. This can also change with the season, where ends are left open through the summer to increase air movement but closed to maintain temperature through the colder seasons.

BENEFITS	DRAWBACKS
Increased permanency	**Cannot easily be moved year to year**
Increased durability • Proper wind and snow bracing, proper anchoring	**More expensive** (price per square foot) than umbrella structures or caterpillar tunnels
Increased climate control • Vents, louvres, gables, fans, basic heating	**Requires time and skill to build**
Potential for four-season growing • Inflated double layer of plastic to help buffer harsh outer temperatures	**Heating is possible, but in-efficient** Double-inflated poly retains some, but not all heat
Potential for increased automation and technology	
Longer lifespan	
Potential for total separation from the outdoors • Increased control over biosecurity (passive pest and disease movement is restricted)	

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Figure 4. An example of a high tunnel with the sides rolled up. A rod is used to adjust the height of the opening, and degree of air movement through the tunnel. This can be adjusted manually or automatically. Note the solid base along the bottom of the tunnel, which helps to insulate the structure throughout the winter. Photo credit: Talia Plaskett, Perennia

Unheated winter production is an option in these structures, but the plants will require extra protection throughout the coldest months. Row cover can be used to buffer the plants through the low temperatures, but can be labour intensive when it comes to addition, removal and adjustment of the row cover to accommodate changes in the weather.

Figure 5. An example of a Quonset-style high tunnel. Notice the extra reinforcement inside the structure compared to the basic caterpillar structure. Pictured on the ground on the left side is a crank used to adjust the size of the side vents. Picture credit: **https://www.greenhouseht.com/quonset-greenhouse**

For areas that receive a lot of snow, a peaked (Gothic style) structure is recommended. The slope of the arch allows a highly uniform transmission of light and decreases condensation on the inside. These have straight walls, creating a higher profile for taller crops, and a more consistent growing environment. These hold up throughout the winter as they can shed snow from the rooves easier than a rounded (Quonset style) structure. The rounded style tends to accumulate snow, risking damage to the structure, and therefore is not ideal for four-season growing unless supporting hoops are placed close enough together to withstand the pressure of the snow. Having a heating system inside will help to melt snow that has accumulated on the roof throughout the winter as well. Quonset-style structures can have straight or rounded sidewalls.

Figure 6. An example of a gothic-style greenhouse. Notice the height of the structure, allowing for tall vine crops to be grown in a more uniform environment the degree of structural support in the end walls. Photo credit: Talia Plaskett, Perennia

Crops Grown

- Vine crops (tomatoes, cucumbers, peppers, eggplant)
- Berries
- Flowers
- High value, quickly maturing crops with a long harvest season

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MULTI-BAY STRUCTURES

Hoop houses can exist as stand-alone features or large multi-bay structures, which is a series of individual arched bays (ideally not exceeding 30 ft wide) that are connected to form a large covered production area. Individual bays can be hundreds of feet long, and heights are typically 7-15 ft at the peak. Each bay has its own plastic-covered roof, while the support posts between bays are shared. The supporting posts between bays are not covered, allowing uninterrupted movement from one side of the structure to the other.

BENEFITS	DRAWBACKS
More cost effective (price per square foot) than a 4-season, stand-alone hoop house	**More expensive (price per square foot) than a more basic structure (umbrella-style structure, caterpillar tunnel)**
Height allows for easy passage of certain spray equipment and tractors	**Supplemental heating is not recommended**
Hold higher temperatures compared to an open field	**Plastic removal recommended for wind events and winter** • Maintain structure (and plastic) integrity
Flexibility in what can grow in the space • high 'ceilings'	**Single sheet of plastic** • Lower capacity to retain heat compared to a double layer of plastic
Potential for electricity and automation • Automatic rolling of side walls, running fans etc.	

While large areas of multi-bay high tunnels are a possibility, it is important to note that the risk for snow collapse and wind damage is higher in structures exceeding 96ft long. It is also important to consider the ability to vent the structure – the longer the structure, the more difficult it will be to have airflow through the entire production space. Long tunnels can also impede work productivity by creating a mental block.

Crops Grown

- Vine crops (tomatoes cucumbers)
- Cane berries (raspberries, blackberries)
- Strawberries

Figure 7. An example of a multi-bay high tunnel. Notice the uncovered support posts that allow for continuity throughout the space.

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GREENHOUSE

Greenhouse structures are a significant step up from a stand-alone high tunnel. These structures typically have concrete flooring, compared to a soil base. They are typically customized in size, compared to other tunnel systems with more standardized sizes. Greenhouse cost will depend on the type of covering used, the size of the space, indoor components, and the degree of automation.

BENEFITS	DRAWBACKS
Permanent structures	**Expensive to manufacture, ship and install**
High degree of environmental Control	**Degree of maintenance required to keep everything running smoothly**
Function to maximize light capture	**Still see climatic influence from the outdoors** • Heat loss through glass/ poly in the winter
Highly durable structures	
Less replacement of structural components from year to year	
High degree of separation from the outside allows for good control over pest and disease movement	
Efficiency of fertilizer, water, and pesticide inputs	
Huge potential for technology and automation	

Although there is still climatic influence from the outside, for example, temperature and sunlight, there is a good deal of manipulation that can happen on the inside to create a balanced environment for the plants to grow in. Temperature, humidity, CO2, lighting, air movement, growing media and nutrient availability can be strictly monitored, measured, and adjusted to create the ideal growing environment for plants.

Capturing light is a key component of greenhouse growing and minimizing the above-ground hardware is a good goal for every space. Every one percent reduction of light can correlate to one percent less production. Re-location of overhead pipes to 'under ground' locations increase the amount of light hitting the crop. Every light installment, support beam, heating pipe that intercepts incoming solar radiation is a lesser percent that is used for production. Many greenhouse technology groups have products with thin profiles to achieve maximal light passage into the crop.

Figure 8. A greenhouse used to grow high-wire cucumbers. The addition of lights, in this case, was to allow for four-season production. Notice the thin profile of the lights, which reduces shadows cast on the crop from the overhead sun. Photo credit: Talia Plaskett, Perennia

Greenhouses are extremely high humidity environments. Every component in the growing space needs to be designed to handle moisture; otherwise, significant rusting will take place and end up costing more in the long run. Growing computers and anything that is unable to withstand wet and warm environments need to be placed somewhere more suitable, like a designated office area. Surfaces within the greenhouse should also be easily cleaned and sanitized. Growing materials like wood, for example, are extremely porous and therefore extremely difficult to fully sterilize. Stainless steel and plastic are much denser, therefore significantly less permeable to pathogens and insects and better suited for production. It is also highly advisable to use greenhouse-specific companies in the design. Electrical and plumbing needs are different in greenhouses compared to residential spaces and should be approached as such. When planning electrical and heating needs, always consider backup systems. Having multiple small boilers, for example, is better than one big one. Reduced capacity to heat is more ideal than total inability to heat.

Crops Grown

- Vine crops (tomatoes, cucumbers, peppers, eggplant)
- Berries
- Leafy greens and herbs
- Cannabis

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INDOOR FARMING

Indoor farming, or controlled environment agriculture (CEA), is a relatively new growing practice. In this kind of environment, there is no influence from the outdoors. The entire facility is cut off from the outside, requiring the growers to fully supplement and monitor the growing conditions. Due to the range of facilities that can be used for indoor farming, there are no 'standard' sizes when it comes to this method of production.

Benefits	Drawbacks
Complete control over the growing environment • No variation when it comes to crop schedules – consistent, reliable harvest every round	**Need to supplement heating, lighting, CO_2, oxygen etc. year round** • Makes up significant portion of initial investment, as well as monthly energy cost
Buildings are well insulated • Less heat/light lost to the environment compared to other structures	**Total reliance on electricity** • Shortages in power could result in crop loss
Possibility for vertical farming • Small footprint with high potential for production	**Takes time to master environmental control and crop supplementation**
Can take advantage of existing structures (converted warehouses, storage containers, etc)	**Most expensive way to produce a crop in terms of inputs**
Plants can divert all their resources to growth • Healthier, stronger, and tastier where there are no harsh environments to respond to	

A unique component of indoor farming is the movement of air in the facility. Due to the separation between the outdoors and the growing environment, HVAC is crucial on many fronts. Not only does it move air and CO_2 through the facility to the grow rooms, but it also facilitates air exchange and ventilation to each room. Humidity management in indoor spaces can be very tricky, and proper consultants should be used in the planning process. Forgetting to account for plant transpiration, regular misting, and irrigation events, will mean failure of the HVAC system to provide a healthy and sustainable growing space. CEA has a high degree of control over the air compared to other growing systems. All incoming air can be cleaned and filtered, removing spores from the outside air, and reducing accidental inoculations of the crop with airborne pathogens and pests.

Indoor spaces share some commonalities as greenhouses. All surfaces should be designed for high humidity growing conditions and be easy to clean and sterilize between production cycles. The layout of electrical, plumbing, HVAC and lights should be put together by greenhouse-specific experts so that the space is user-friendly and can meet the needs of the grower. Indoor farms, like greenhouses, are spatially separate from the environment, meaning there is a high level of control over the diseases and pests that move into the space. Strict biosecurity protocols are crucial to minimize the main routes of entry for these detrimental pests and disease.

Indoor farming also allows for the possibility of vertical farming. While the idea of being able to utilize vertical space, instead of spreading out over a larger piece of land, is attractive, it is not without its challenges. The key for vertical farming is being able to provide steady growing conditions for each level of production. Temperature, airflow, humidity, and light levels need to hold steady for each tier of production, and this becomes difficult to regulate at higher platforms without significant investment in the facility.

Crops Grown

- Leafy greens and herbs
- Microgreens
- Cannabis

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CONCLUSION

When it comes to protected production, there are many options available when it comes to structure. Tunnel height is a big factor to consider in the decision-making process, and it is up to the grower to decide what makes sense for the target crop. Tall tunnels provide a stable and consistent growing environment for the plants and are recommended for taller vine crops and raised berry production. Short tunnels are much more prone to having hot and cold spots, but for a space that is designated for low-lying crops, a lower peak is adequate. It is also important to consider the production site (exposed versus sheltered site) and growth trajectory of the farm.

The movement into a protected space can be challenging, and it is important to recognize that common growing practices outdoors may not always match up to what happens indoors. The suite of pests and diseases will change as well, so be equipped for symptoms that appear differently. Despite the potential for growing pains, protected production is a key tool for agriculture success in a changing climate. Don't hesitate to reach out to **Nova Scotia's Protected Crop Specialist** for guidance and support throughout the process.

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