Proceedings: Profiting from your Greenhouse Effect: the Essentials of Season Extension

Atlantic Canadian Organic Regional Network

February 28-29, 2012, Debert, Nova Scotia

Introduction

Greenhouse production has always captured the imagination of gardeners and vegetable farmers both for the tremendous potential to produce food and its appeal as a warm and sunny refuge on cold, spring days. In the past, greenhouses were often considered hot houses because the glass or plastic structures were heated with wood or oil. Nowadays, simple plastic structures are used to grow vegetables in the shoulder seasons and sometimes the dead of winter without supplementary heat. Hence the term cold frame and tunnel house. The realm of knowledge about greenhouse and tunnel production continues to grow exponentially, and it was with this in mind that ACORN decided to hold its first workshop or mini-conference dedicated to season extension.

Greenhouse growing plays a vital role in organic horticulture and vegetable production because it produces both out-of-season crops and the transplants needed for main season growing. It is a reasonable assumption to say that most organic vegetable growers in Atlantic Canada use at least one basic greenhouse structure, if not several full-size greenhouses and tunnels, in addition to growing field crops. New entrants to vegetable production often dream of constructing their first greenhouse. The yields and quality of vegetables produced under plastic can indeed be impressive, but this does not mean management is simple. In the 1970's, there were at first one, and then two, provincial greenhouse specialists working in Nova Scotia. Greenhouse growers had monthly meetings with invited speakers to discuss important topics of production. The greenhouse business was considered a technical and complex field, and growers recognized that staying up to date on the latest technologies and learning from fellow growers was an important part of success.

A successful greenhouse workshop in Bouctouche, New Brunswick, last November organized by Claude Berthélémé and ACORN, was a reminder that many new organic growers take a rather haphazard approach to greenhouse management. Learning the principles of effective light, heat, water and fertility management can lead to enormous gains in productivity and substantially reduce workloads. Granted, assimilating the knowledge and implementing the growing techniques seems like a tall order sometimes because many small-scale growers usually manage multiple crops, including transplants, in the same greenhouse. Most organic greenhouse growing is far more knowledge-intensive than growing tomatoes and cucumbers.

“Profiting from your Greenhouse Effect” was first envisioned as a day-long workshop to cover a few basic but essential topics for new greenhouse growers. As interest picked up, demands for sessions on more advanced topics became evident. The trick then was to strike a balance between basic and advanced topics within the constraints imposed by the limited funding at ACORN's disposal. Thanks to

the generous contributions of sponsors from the greenhouse industry and agencies in the Nova Scotia and Federal governments, ACORN expanded the program to include an overnight, an evening forum and a second day which included some more advanced presentations about soil fertility, transplant production, tomato grafting and greenhouse design. ACORN hopes that this workshop will serve as a stepping stone to further events focused on season extension. Presentations provided by the speakers have been recorded on the ACORN website, accompanied by notes about additional information provided by the speakers and the many excellent questions and comments from the audience.

Day 1 (Tuesday Feb 28)

1:15-2:30 **The greenhouse effect: the influence of light, water and heat on plant growth**
with Lloyd Mapplebeck, Nova Scotia Agricultural College

There are a variety of different greenhouse styles available. They may range from simple lean-tos built next to an existing structure to unheated structures such as small poly tunnels and Haygroves to larger heated structures with a double layer of poly over galvanized steel. Some materials that may be used to cover greenhouse structures include polycarbonate, glass, and polyethylene. The important thing is to go with scale that is appropriate to you.

The basic requirements for plant growth that must be considered in a greenhouse environment (nutrients, water, CO_2, light, proper temperature):

1. **Nutrients**

Plant nutrition must be considered in the context of the substrate being used. For example, in the case of hydroponics where the medium is water, the grower has more control over the nutrients that plants receive than in soil that may have existing nutrients. If growing directly in soil, soil testing is advisable.

2. **Water**

There are four primary roles of water:

1. Water acts as a solvent in which necessary chemical compounds and gases are dissolved. Water is the medium by which plant nutrients enter cells.

2. Water is the reagent required for many cellular reactions in plants.

3. Water provides plant cells with the turgidity required to maintain their structure.

4. Water serves as a plant coolant via the process of transpiration through the plant's stomata.

Most plant species are composed of 90-95% water. Lettuce for example is ~95% water. To properly meet plant water requirements, operating a greenhouse requires a lot of water. Lloyd's perennial

nursery Hillendale requires about 2 million litres per year. Trickle irrigation systems use 20% of the water normally required; however they can require a substantial investment to install.

Proper watering is critical in maximizing greenhouse crop productivity. Too little water will result in desiccation. Too much water can result in saturated pore space and not enough available oxygen for the plant roots.

Watering is an art and how to know when to water requires experience. It requires a lot of judgement and knowledge. Just looking at the surface of the media to assess whether the plants have enough water can be misleading as it doesn't indicate whether there is water available for the roots. With experience, a grower should be able to know whether a tray or pot needs watering just by its weight.

It is best to water earlier in the day to give the water a chance to percolate down to the roots so the plants can withstand the heat of the day; also, early watering can help in avoiding diseases, burning of leaves etc. However, if the plants are really parched for water, you may water in late afternoon.

Water quality is very important. Greenhouse growers must consider potential contamination from sources such as gypsum, potash, NaCl deposits. At Hillendale, they constructed an earthen berm to keep NaCl out of their irrigation pond. Growers should monitor the pH and alkalinity of their water.

Root water stress can have a number of causes including not enough water, the presence of salts, or the presence of diseases. Stress can also occur even if there is sufficient water under conditions where it is so hot that plants cannot take up water as fast as they transpire. In addition, some plants (e.g. carnations) simply do not adapt fast enough to their changing environment; an effect that Lloyd calls "lazy plant syndrome".

Humidity must also be considered in the greenhouse environment. The grower doesn't want 100% humidity because that creates an environment prone to condensation and disease. Humidity may be controlled using ventilation and/or temperature. The heat in a greenhouse can be turned on to dry the greenhouse out and to avoid disease problems like dampening off. In the case of plants which are prone to dampening off such as ageratums, celosia and statice, it would be advisable to put them in the center of the greenhouse or close to a heat source.

Additional notes on water:

- When installing your irrigation system, Lloyd suggested that a bypass line is worth considering as it may help to avoid burning the pump out.
- A lot of water comes off the top of the greenhouse roof. You may require ditching if water accumulates.

3. **CO_2** - One of the two compounds required for the process of photosynthesis. Plants convert CO_2 and water in the presence of light energy into carbohydrates and oxygen. This process enables plants to create their own food so that they may grow.

4. **Light** - Growing plants is harvesting light. The greenhouse grower wants to maximize this as increased light means increased productivity.

Sun is the primary source of light, but some growers supplement for higher value crops.

Primary photoresponses in plants:

1. Photosynthesis is the most important. It is the process by which plants manufacture their food. Light energy is required to convert CO_2 and water into glucose.

2. Chlorophyll synthesis – chlorophyll can only be created in the presence of light. With species that require darkness to germinate, be sure to check them for germination, otherwise, they may emerge without proper chlorophyll development, thereby weakening the plant.

3. Phototropism is simply a plant's tendency to grow in the direction of a light source. This is an important consideration for ornamentals where aesthetics are important in successfully marketing your crop.

4. Photoperiodism is a plants reaction to the length of day or night. It is how the plant detects seasonal changes and knows when to flower. There are short day, long day and day neutral plants. Many brassicas such as Chinese cabbages are long day crops and must be planted at the right time to avoid bolting.

5. Photomorphogenesis – leaf expansion etc.

Light intensity is an important consideration in maximizing plant growth. Growth rate = photosynthesis minus what is used up by respiration, so you want to maximize photosynthesis rate by maximizing the light that enters the greenhouse.

"Light compensation point" is when the energy gained from photosynthesis is equal to that lost through respiration; therefore there is no net gain. In our region, this happens around mid November. The "light saturation point" is when there is no gain to the plants when additional light is added. At peak (June 22), this can be three times what is actually needed. Growers may need to shade under these conditions.

When considering greenhouse orientation, an east to west orientation (of the ridge of the greenhouse) is usually optimal for maximizing the amount of sunlight that enters the greenhouse. A north to south orientation results in more reflection. However, you also need to consider where light goes throughout the growing season(s). For example, the greenhouse may be shaded later in the season.

The Greenhouse Effect - Once solar radiation hits plastic and passes through glazing materials, the short light waves convert to long wavelength thermoradiation (heat). Glass is better at trapping in thermal radiation. With plastic, you need two layers of polyethylene so that the air between the two layers of film acts as an insulating layer. However, with each additional layer, 10% of light is lost. Light essentially

equals productivity, therefore by adding an extra layer of polyethylene, you lose 10% light and ~ 10% production.

The greenhouse producer must consider other aspects of their greenhouse structures. For example, structures made with 2x4's are going to block out a lot more light than galvanised steel. In addition, cracks in the greenhouse covering will directly impact energy efficiency of the greenhouse.

5. Proper temperature

Greenhouses heat up for two reasons: 1. because of the "greenhouse effect" 2. because the greenhouse is an enclosed space. The extent that greenhouse temperatures rise above outdoor temperatures depends upon the amount of solar radiant energy being transmitted through the greenhouse covering, what happens to that energy and how much is retained within the structure.

Greenhouse temperatures are influenced by many of the same factors that influence greenhouse light intensity: the type of structure, the covering materials, the greenhouse's orientation, latitude, time of year and shadows. The heat in the greenhouse may be supplemented using wood or oil heat furnaces.

Greenhouses temperatures can be broken down into air, leaf, substrate and irrigation water temperature. The leaf temperature is actually higher than the air temperature. Photosynthesis increases as temperature increases (as does respiration). The optimal night temperatures and the optimal day temperatures both play a factor. For example, with spinach, the optimal night temperature is 10°C and the optimal day temperature is 15°C.

The temperature of the substrate (growing medium) affects the decomposition rate and availability of nutrients. Below 10°C, microbial processes slow down. Substrate temperatures also impact diseases; for example dampening off by *Pythium* (which is generally worsened by colder temperatures) and *Rhizoctonia* (which is more severe at higher temperatures). In unheated structures, there is a lag phase whereby the substrate gives off heat at night. The amount of heat retained by the substrate can be affected by factors such as open vs. solid bench and the thickness/volume of your trays.

The optimal water temperature depends on the plant species. For example, spinach and tatsoi grow well with a water temperature of 6-8°C. Basil needs warmer water. (note: There may be increased disease problems with cold water.)

Different crops have different optimal temperature ranges for seed germination, growth and development. These crops can be broadly divided into three categories: cool-season, moderate-season and warm-season vegetable crops.

Optimal ranges for different crop types:

Crop type	Examples	Seed germination			Development		
		Min	Opt	Mac	Min	Opt	Max
Cool season crops	beets, broad beans, broccoli, brussles sprouts, cabbage, chard, chives, collards, garlic, kale, leek, onion, parsnip, peas, radish, rutabaga, shallot, spinach	2	10-20	35	4	13-24	30
Moderate season crops	Artichoke, carrots, cauliflower, celery, chinese cabbage, endive, lettuce, lima beans, mustard greens, parsley, potatoes, snap beans, sweet corn	4	13-28	35	7	15-26	32
Warm season crops	Cucumbers, eggplant, melons, okra, peppers, pumpkins, squash, sweet potato	15	20-30	40	15	18-25	37

Additional notes on specific crops:

- At 27°C bottom heat, cucumbers will emerge in 48 hours (outdoors, there is much more variability and it can take weeks before the soil temperature is appropriate for germination)
- Basil can be damaged at 10°C.
- Peppers can be damaged at 5°C.
- Kale can withstand temperatures as low as -14°C!

Questions:

1. From November to mid-February when it is cold, there can still be lots of condensation. What to do in the absence of heat or fans with a polyethylene structure?

A: Can use minimum heat. This can even be useful come March. You can get an inexpensive heating system and just turn it on when you need to dry the greenhouse out.

2. In your slideshow pictures, why were some of the tunnels so high?

A: For air circulation and to enable more light to get in. This definitely results in more surface air and a greater energy requirement to heat that additional space, however once it's heated, it's heated. You could also invest in thermal curtains to keep more of the heat in. When greater than 20 feet, gothic arch, there is more structural strength and the greenhouse is less likely of having the structure collapse from snow.

3. Heat vs. light with one versus two layers?

A: You will need to do the math, which will vary depending upon what you have. It depends on the crop and whether it is worth it (value of crop and tolerance to cold). Losing 35-40% heat with only one layer. But if using wood, heating energy is cheaper than if using oil thus you might calculate that it is OK to go with one layer.

2:30-3:30 **Choosing greenhouse structures to meet your needs and future trends in plastic**
with Vincent Dieras, Halifax Seed

> *"Very good planning is critical. Consult with others!*
> *The more ideas and input you get, the less likely you are to make mistakes."*

When you are choosing the greenhouse style that is appropriate for you, consider your needs in terms of optimizing plant production and maximizing your profit margin.

The primary reason why farmers construct greenhouses is to extend their growing season. Season extension makes you much less vulnerable to the unknowns of the weather from year to year. It enables you to be able to be much more reliable in what you are able to offer, enables you to grow a wider variety of crops and extends the amount of time you can grow by 25%. This is immensely valuable in increasing your profit margin by being able to offer crops out of season.

Considerations before building a greenhouse:

Site location is important for access to processing facility and power (it costs a lot if power is far away). You want the greenhouse to be close to power and water sources. Land and site preparation is important. These can cost as much as the actual greenhouse structure! Do the math first. "Very good planning is critical. Consult with others! The more ideas and input you get, the less likely you are to make mistakes." Do detailed planning on graph paper and include factors such as orientation, surrounding structures, water source, power source, processing facility, drainage etc. (Note: a 2% slope is needed for proper drainage.)

If you have a large operation with numerous greenhouses and if space permits, be sure to put different crops in each greenhouse so that the requirements of each crop can be better controlled for. This also helps to make pest control strategies more straightforward. If you have fewer greenhouses, then maybe at least do your planting grouped by plant families.

There ought to be at least 20 feet between each greenhouse so that there is enough space to remove snow and allow light to penetrate the greenhouses.

When planning, consider labour requirements such as efficiency in ease of harvesting and weeding. Everything should be set up so accessible to labourers so that they may work efficiently. Also, the entrance should be big enough for largest piece of equipment you want in there. Also, consider access roads for tractor-trailers and other equipment.

In the spring, you want to melt the snow as soon as possible. The increasing fluctuation in climatic conditions means that growers need to plan for all possible climatic conditions. Most gutter-connected greenhouses can withstand 50 lb/square foot. More steel can be added to make the greenhouse more structurally sound, but this costs more to build and also reduces light penetration. You should have the ability to melt the snow during the winter. With freestanding, can just remove snow from the side. Therefore gothic style is most popular because stronger and can shed the snow more readily. Don't

remove all the snow from one side of the greenhouse at once. It is better to remove a little at a time from each side so that you don't leave a whole bunch of weight on one side of the greenhouse at once.

Light is critical. At our latitude, it is best to have the ridge running from east to west to maximize the amount of southern exposure during the winter months. Orientation to sun is important, but sometimes not possible depending on lay of the land. E.g., if it would be water not being able to properly drain.

It is important to know the marketing route you want to take. Have a five and ten year plan on where you are going. Start implementing where you are going into your present plan.

Consider the weight of the crop. For example tomatoes, cucumbers and hanging baskets can create a tremendous weight stress on the structure, thus you may want to reinforce the structure. Single tube cross tine to run wire to string tomatoes from.

Be mindful of the National Farm Building Code. Greenhouses must be able to withstand 50lb/sq foot. Design Load – dead load = weight of the structure. Live load (variable) – wind/snow, NGMA (National Greenhouse Manufacturers of America) 15lbs min/ sq ft.

Don't underestimate the strength of potential winds! The foundation should be pounded into the ground 30-36". The foundation can be bolted to a flat bottom bracket. The base must be bolted to the ground. You want the structure well secured into the ground. This can be achieved by installing a ½ inch rebar at 21 degree angle perpendicularly crossed over to anchor, pounded into ground at least 3 feet, every 10-12 feet. And you want the structure anchored before you put the covering on!

If a storm is coming, make sure all doors are closed properly! Put cinder blocks in front of the doors or lock them to control for potential wind damage; and make sure sides are securely rolled down.

The different styles of greenhouses available:

There are four major kinds of greenhouses: High tunnels, Cold frames, Freestanding and Gutter connected.

1. High tunnels are strictly season extenders. They are not for year round greenhouses. High tunnels cannot handle the snow. The plastic must be taken off.

2. Cold frames are the easiest to install. They can be approximately 30 feet wide and may be used with or without heat.

3. For actual year round greenhouses, freestanding greenhouses are the first thing people start with as they are the easiest to construct.

4. "Gutter connected" means multiple greenhouses connected by gutters. Gutter connected is worthwhile if you have 10,000 square feet or more. In areas where excess heat is a problem, for example Southern Ontario, you need at least 90 foot long greenhouses. With gutter connected

greenhouses, it is best to have gothic style so that condensation will go to the sides and not fall onto crop. Also, you want 12-20 feet under the gutter.

High tunnels are quonset shaped. Cold frame, freestanding and gutter connected are all gothic shaped.

Cold frames are 18-20 feet wide, high tunnels are 20-30 feet wide, freestanding are 24-30 feet wide and gutter connected are 18-30 feet wide with an undergutter of 12-20 feet.

The difference between cold frame and freestanding is that cold frames are not designed to any building code. Also, the shipping weight of a coldframe is 15lbs/running foot. For freestanding greenhouses the shipping weight is 35lbs/running foot. There is also a difference in the cost per square foot:

Cold frame cost evaluation: $1.18 /square foot.

Freestanding greenhouse cost evaluation (depends upon the size):

24'x48' = $1.83/square foot
27'x48' = $1.67/square foot (Cheaper per sq foot because higher ceiling, thus reduces cost)
30'x48' = $1.73/square foot

With any high tunnel structure, you must remember that you have far more surface area for water to pool in. The water has to go somewhere! You don't want to lose soil and end up with muddy areas. To avoid this, a gutter may be installed to use for irrigation and direct water to a pond.

Ventilation:

Ventilation is extremely important in a greenhouse environment as it helps control plant stretching and diseases. There are three possible ways to ventilate your greenhouse: with an exhaust fan, with roll up side vents, or with roof vents.

It is much easier to move air from side to side for ventilation. With roll up sides, you don't want more than a 30 feet wide greenhouse. Roll up sides are the most efficient method of ventilation. Exhaust fans are not practical over 100 feet. For extra ventilation can have sides that roll up high combined with roofs that open.

Considerations in selecting your covering:

With polyethylene, you want two layers, especially for larger structures. The double layer is much more efficient for energy, and also much more structurally sound. The layer of air actually strengthens the structure. You want to reduce the layer of condensation trapped between the two layers so that as much light is able to penetrate as possible. High pressure sodium lighting is not worth the cost.

Fiberglass is no longer used. Acrylic is strong but very costly. The problem with woven fabric is that it accumulates a lot of dirt and light transmission is reduced quickly. For mass production, single and double polycarb are the best investments. Gable ends.

Thermax should be used on the inside layer… reflects the heat on the inside of the greenhouse. 4 year film (SDF4) on the outside. This is the optimal combination. Thermax has less dripping on the plant, less condensation and better light transmission.

There is also red tinted poly for growing tomatoes. Trials are presently being conducted on their effectiveness.

Additional notes:

You can have a layer of plastic that you roll over the crop. This can provide increased frost protection. But be cognizant of potentially creating an environment for diseases (high humidity).

"Wire poly-lock" "double wire poly-lock" – enables plastic from the roof to be completely independent of the plastic from the side.

Questions:

1. Do you believe the trade off of losing light penetration with two layers of polyethylene is worth the energy savings?

Answer: Yes, two layers of polyethylene reduce heat loss by 33-40%. Also, the two layers makes the greenhouse more structurally sound.

2. How many years can you get out of greenhouse plastic?

Answer: After four years, the light transmission will drop dramatically and this will result in stretched plants.

4:00-5:15 **Greenhouse construction from the ground up (DRAFT)**
with David Blanchard, Pleasant Hill Farm

David began his talk by saying:

> *"There's no single right way; on the other hand there are some things that are just plain wrong."*

On his farm, they mostly use pre-fabricated greenhouses. Cautionary tale on using wood based structures: they last 8-10 years before ending in varying states of decay.

Good tools are very important. He extolled the virtues of vice grips! There are many types of vice grips that can be useful in greenhouse construction. You want good step ladders tall enough so that you don't have to work on the top rung.

Site considerations: slight slope: 1-40 degrees is OK. Aspect: due south is ideal. SE or SW are good. Consider if shade will be a problem in any season. Consider drainage; don't build in a wet spot. Don't do tillage work in advance. The ground will become a muddy mess and compacted by foot traffic anyway.

The first step is to lay in and count out ground posts. They are the foundation of the greenhouse. If not done properly, the rest of the greenhouse will be flawed. It's worth it to take extra effort to do it right from the start.

Use a string and stretch it tightly to make sure posts are straight. Set the height where the bolt holes should be. Support string in the middle by bracing with wood because it will sag. Otherwise you will have sagging in your greenhouse.

Use the spacing board. Hook into first post and it will tell you where to pound in the next two posts. The notches need to be a little bit bigger than the board, otherwise it will be split. The posts go into the ground about three feet. This is the most physically demanding stage of greenhouse construction. Use a 12 pound sledgehammer. David says "I'd rather have fewer heavy hits than lots of light hits". You're less likely to damage the post with fewer hits. Galvaninzed steel posts will last 40 plus years.

The metal sock that goes over the post is important for protecting the post. If the manufacturer doesn't send it with the kit, buy the biggest bolt possible from the hardware store.

David noted "It's really important that the arches of the greenhouse be vertical to the ground". If the arch is leaning, the force from the snow doesn't get transmitted into the ground. Eventually, the structure will fail. Take the time to do it right! It takes 5-10 minutes to do each post right.

What happens if you hit a rock? You will, and you might be able to pound right through. But if there is no give, then you must stop because it will cause the post to bend. Rule of Thumb: You can afford to lose 6 inches of depth on two or three posts on each side. If you're losing more than 6", you'll have to dig the rock out. Put crossposts in to give more holding power.

The fussiest part is the shape. Use basic geometry to get the angles right: Pythagorean Theorem. You use the diagonal to get the corners. Use **two** tape measures to see where they intersect… there is only one possible spot (With multiples of three, you can do the math in your head). Use the same to get your fourth corner and stretch the string between them. A reasonable goal is to be within 1" on each side.

Once posts are in, assess how damaged they are. If they are two beat up to let the arch post slide over it, you want to know that before you're half way through installation. You can hack off the top of the post with a file, hacksaw or grinder. Get the first three or four sets of arches so that they're nice and plumb. Then the rest is easy. If the arches are not plumb, they are more likely to collapse under snow.

Use a tapered line up punch to align the hole (you can get from anywhere that sells automotive tools). A Pipe wrench vice grip can grab hold of things that are large in diameter.

If holes absolutely won't line up, a drill can be used to enlarge the existing holes. Ridgepoles are used to tie arches together. Install the purlins with the bolts snug, but not tightened dead tight. Use a comealong to pull the arches right where you want them if there is any lean to them.

Hang the plumb bob from the peak of the first arch. Pull the arches with the comealong until the plumb bob is aligned. Once those 3-4 arches are dead right, it's fast to do the remaining arches. Make sure you give yourself enough time though to get the remaining purlins and braces on the rest of the arches all at one time (otherwise there is a risk of damage if it gets windy).

Crossties: used for greenhouse tomatoes and cukes. Make sure the height is where you want your trellises to be tied (David uses 8 feet). The king post keeps the crossties from sagging.

He says "In isolation, each piece is not very strong. The more places you can unite the pieces, the stronger the entire unit becomes".

Baseboards do not come with the kit. If you don't use roll ups, then the baseboards are the attachment point for the plastic. Wind has a lot of strength, so you want to ensure that it is tightly secured to the baseboard. Baseboards will tend to rot. Can't use pressure treated wood. David uses "eco wood treatment" or linseed oil. Also, leave at least an inch off of the ground. Don't put baseboard right on ground. Use insulation to fill the gap.

One of the biggest infiltration points for heat loss is at the base. Must insulate the perimeter. Put the insulation board right into the ground. The polylock channel is held in place. Inner board, insulation, outer board. Use a c-clamp vice grip for locking the three layers in place. To hold in place, 5" carriage nuts with a washer. Use really good heavy deck screws with galvanized coating. Dig trenches by hand and leave 3" between insulation layer and ground posts. Don't dig up the whole thing at once. Tamp it in by just deliberately walking along the edge.

The eye bolt on the bottom is important to keep the rollup held back against the building. The zigzag rope keeps it tight. David loves the roll-up. Between 8x8' doors on each end and roll ups, he gets sufficient ventilation in his 20'x60' greenhouses. Just like the baseboard, the rollup board must also be solidly anchored to the frame. Use a washer and bolt (~5/16ths" bolts; might need ¼"). Use a narrower board than baseboard.

Use string to align where rollup board should go (using vice grips to avoid sagging). The higher up you put the board, the better the ventilation. But you can have problems with too much wind. This would be problematic for the delicate flowers and developing fruit of tomatoes. You want to run any screws with the tips in and the heads out to avoid tearing plastic. Can buy clips that are a short piece of poly lock wire. Put rope behind that and looped through zigzags. Use poly lock wire instead of hooks.

C clamp a piece of wood between the roll-up and the baseboard and shape it and carriage bolt it to bridge the gap so that the end plastic can fit snug next to the end post.

The type of endwall you choose depends on what you're going to do with the greenhouse. David uses wood framing.

Plastic installation: Don't install when it's windy! Start at daybreak. You need at least four people. Five-six is better. Easiest if you use staging to ease the plastic on. Make sure the coating is facing the right direction! You'll need someone inside on a stepladder to guide the plastic over the arches.

Once the first layer is on, the 2nd layer goes over easily. With staging and five people, first layer takes 15 minutes. 1 ½ hours to do the whole thing including polylocks. Put one piece of polylock in each corner to hold it in place and to keep the right amount of overhand.

David uses double poly on end walls and inflates them too just by using a jumper hose.

Amazing resource available free! Greenhouse Engineering is available free on the internet in pdf form!

http://host31.spidergraphics.com/nra/doc/Fair%20Use%20Web%20PDFs/NRAES-33_Web.pdf

Questions:

Tightness of the poly: with double poly that you will inflate, make it only tight enough so that there are no sags and folds. With a single layer, you want it as tight as you can. But take into account that if you are installing in the heat of summer that the plastic will tighten more come winter.

7:00-9:00 **Evening forum: "My biggest mistakes and greatest successes" Experienced growers share advice with up-and-comers**
Panelists: David Blanchard (Pleasant Hill Farm), Josh Oulton (Taproot Farm), Tim Livingstone (Strawberry Hill Farm), Norm Eygenraam (Multi-Shelter Solutions), David Greenburg (Red Fox Farm) *Moderator: Rupert Jannasch (Ironwood Farm)*

The evening forum began with each of the panelists sharing at least one success and failure.

David Blanchard

Success story: Heated seed germination table enabled David to start transplants in his basement with incredible success. With the system he designed, tomatoes germinate in three days! The germination table is a simple greenhouse bench with wire mesh over top. The bench is 4.5 feet wide and 12 feet long. A circular coil of hot water tubing runs underneath. A mixing valve is used to control the water temperature so David could make the temperature of the mixing valve the temperature he needed to germinate the specific crop.

David also considers the production of pea shoots and sunflower shoots a success story. The economic breakdown of shoot production: $20 worth of seed, $10 hours labour, $25 power; converted to $500 of

pea and sunflower shoots. This is excellent supplemental income at the farmers' market booth in June/July when salad is doing poorly. Salad would sell out first, but once it what gone, customers went for the pea and sunflower shoots

Disaster: lost tomatoes.

Tim Livingstone

Failure: several acres of strawberries in winter. There is not enough light in our region to produce strawberries in the winter. The berries were insufficient in both size and flavour. Tim believes that no matter what, you aren't going to get the flavour you find with outside strawberries. Even when they grew strawberries in the greenhouse during strawberry season, the flavour simply wasn't there. He attributes this to the lack of temperature fluctuations that you would find outside.

Many failures before it became a success: Learning how to grow a good tomato plant took time!

Success: Hearing people say "we wish our conventional transplants looked like your organic transplants".

CSA is also a huge success! The connection made with your customers adds so much meaning to the growing experience.

David Greenburg

Failure: When he first started farming, he had start-up money from his parents he was using instead of going to college. He immediately bought and assembled five greenhouses. They all crumpled in a windstorm. He would consider that a failure. And humbling.

Success: finding a scale of greenhouses that works for him and his needs. For him 20 foot coldframes and simple caterpillar tunnels are appropriate for his needs. It is much better to not overbuild and learning that for him was a success that emerged from a failure.

Josh Oulton

Failures became successes:

Haygrove tunnel experienced wind troubles! But Josh learned that wind can be handled with some tricks of the trade. Ropes can provide the strength; just make sure they are tight.

Josh also experienced trouble growing strawberries in tunnels when the crop was infested with two spotted spider mite. However, predatory mites became a success.

Norm

Failure: “if you fail to plan, you’re planning to fail”. But! Always keep flexibility in your plan.

Success: For Norm, listening to David Blanchard talk about his greenhouse successes was his greatest success. The greenhouses David talked about were greenhouses that Norm helped him select.

A note from Norm: if you have an irrigation pond that is 5-6’ deep, you will always have scum. Anything deeper and the water is clear. This same concept applies to air in the greenhouse. It will cost more to have more air space, however this creates a much healthier environment for plants.

Questions:

1. Is it financially worthwhile to buy a used greenhouse? By the time you take it down and put it back up, are you really saving much?

Tim Livingstone figures it saved him about half the cost. He advises to be sure to mark every single piece. Don’t even think of reusing plastic! Aside from the damage it has already gone through, it won’t fit exactly. He purchased a used 30x90 foot from Halifax Seed and was really happy with the quality. He also used the original plastic for cold frames etc.

David Blanchard didn’t have a good experience. He bought it without seeing it standing up in a pile of parts. It turned out that it was missing the joining arches so he had to build them. The parts he required cost him $500. In the end, the materials cost about two thirds what a new one would cost. Plus a lot of additional labour beyond what it would have taken had it been a new greenhouse. David advises that if you buy a used one, get a good deal on it!

Norm Eygenraam says that a good rule of thumb when considering the cost of a used greenhouse is that you want 25 cents on the dollar of a new one.

Also, he says to use high tension bolts. Galvanized steel has about half the strength of steel. It is possible to get a treatment for them for humidity protection.

2. Mobile greenhouses? Are they worthwhile given the structural integrity you would be compromising?

Tim Livingston has used 15x70 foot structures that are 10 feet tall. He has moved them for crop rotation purposes. He moves them on a pipe. He uses a duck bill to hold them down and uses three on each side. To move it, unhook them from the structure and use a tractor bucket to pull them out.

15x25-30’ long used for animal structures. They can be pulled daily on the back of a tractor trailer.

He cautions that you don't want them rolled up more than 4-5 feet high because wind can be hard on tomatoes.

Best of both worlds would be to have moveable tunnels, but also a really well built greenhouse like those built by David Blanchard.

"it's got to be strong enough, but it's got to be able to move"

David Greenburg says beware of "spin in earth anchors" which may be used to secure mobile greenhouses. They will eventually vibrate their way out over time. Therefore you need to reset them or move your house.

Norm Eygenraam says it is really hard to leave anchors in one place. First of all, they may become damaged. Second, once they are out, it is hard to get them back in the right place.

(David Blanchard cautions that you may need permits for greenhouses, so watch for that! In Queens County where he is, it is required. $160 for building permit and structure permit).

3. Is it possible to grow eggplants in greenhouses?

Audience member: No, you won't make money on eggplants. However eggplants are a great trap crop for the Colorado Potato Beetle if you are growing potatoes!

Tim Livingstone found that Galine from Johnny's grew better than Dusty. He does eggplant and peppers around the edges of his tomato greenhouses. Entrust worked well for his CPB control. He waits until there is minor defoliation from the larvae before he sprays for CPB (Entrust). At that time, he does one application. Then 10-14 days later, he does his second application. This timing seems to work well for minimizing eggplant damage.

David Greenburg says that it can be done. He's seen it, but hasn't been able to replicate it.

Josh Oulton had a good experience growing Dusty Eggplant in high tunnels.

Rupert Jannasch had good luck growing eggplant in a Haygrove tunnel. He found less luck in his double polyethylene tunnel.

Josh suggested that the reason why Rupert had luck growing eggplants in the Haygrove and not in his poly tunnel relates to the soil health in your greenhouses. When you have something permanently covered, it never gets those torrential rains that enable percolation. With permanent structures, it might be possible to replicate the effect of torrential rains by flooding the greenhouse. Another option might be to remove that top layer and add a layer of compost.

4. Is there any way to measure light in the greenhouse so that you know that enough is being transmitted through old plastic?

David Blanchard suggests that a Photosynthetically Active Radiation (PAR) meter may be used. (costs about $200-300) PAR meters count the photons of light that matter to plants over the course of a day. When he tested it, they were only getting 60% on four year old plastic.

Tim Livingstone reminded us that the intensity of light coming through depends on the time of year. He has to shade in the summer because light intensity and duration is too high if growing bedding plants.

David B. says that in winter, light is precious. Once the greenhouse is no longer transmitting light very well, then it's no longer worthwhile.

5. As organic farmers, we are all concerned about sustainability and the environment. How do we reconcile that with the amount of plastic used and ultimately thrown out in greenhouse production?

David B. says the only alternative would be glass, but it is prohibitively expensive and a challenge to work with as it really doesn't have any wiggle room. Unfortunately, the plastic is not possible to recycle. You can reuse scrap bits by laying over seeds germinated in cold soil. Doing this can bring the soil temperature up from 6°C to 10°C, which is a good temperature for brassica germination. He gets his brassicas to germinate in 6-7 days in mid February.

Rupert says that there are occasionally environmental programs to take away agricultural plastic.

Audience member: There's a place in Burnside that will pick up plastic.

Remember that the outside layer is cleaner and you can probably get more life out of it.

Tim says that many of the newer plastics actually transmit light as well as glass. They diffuse the light, which makes up for not being as clear.

6. How do you know when to change plastic?

David B. says to "let the plants talk to you". If you notice a decrease in the productivity of your crop, then probably it is time to change the plastic. Also, plastic becomes brittle. Five years is around when it can become brittle. Watch the anchors or other stress points because that is where you'll notice the plastic losing its integrity first.

Tim has noticed that plastic will wear out wherever it's in contact with something dark. Watch those points. It will save you from unwanted surprises.

Audience member: Also, cleanliness can extend the shelf life of your plastic. You can wash mold with apple cider vinegar or tea tree oil. Greenhouses should be washed once a year.

Comments from David B. regarding the economics of greenhouse construction:

Insulating takes a lot of money and a lot of labour. To install, it takes two good workers a day and a half. It probably costs about $1000 to have a nice snug perimeter. The greenhouse cost is $4100 (includes double plastic for end walls). The lumber and other materials for end walls costs about $300. He buys used wood furnaces.

All together, the total cost is $7000 to build a 28x60 foot greenhouse structure. Each year, he gets $8000 for his tomatoes and $4000 for his greens. David calculates that it takes a year and a half to get his investment back and then the greenhouse makes money.

"I can't think of any better place to put money in terms of using money to make money".

7. Shallow anchoring for permanent concrete foundation.

Norm: "the earth anchor" comes in varying lengths. Can use snow posts driven in at alternating angles. He likes t posts better than rebar because t posts will not bend.

8. What would you start with if you just want to do a small market garden?

David Blanchard wouldn't start with something tiny. It wouldn't be worth your time and will just leave you wishing for more greenhouse space. He would start with 20' x 40'.

Norm says it only costs about 10% more to go from 16x24 feet to 20x40 feet.

Tim found that 10x12 feet was only enough for his family and even then it was tight at times.

Day 2 (Wednesday Feb 29)

8:15-9:30 **Secrets of transplant production for organic market gardeners**
with Tim Livingstone, Strawberry Hill Farm

Value of transplants on the farm: no need to thin, weed control, get an early start, get ahead of pests, reliable germination. Allows you to grow a crop you might not otherwise grow. And grow it better.

Seeds: importance of using quality organic seeds: fewer seeds go farther… better germination (not always)

Seeding – better to seed more per cell and weed them out. If you're hand sowing small seeds (e.g. lettuce) can get pelletized with a small coat like clay. Make sure germination %'s are good.

Storing seeds - humidity plus temperature should add up to 100.

Soil – Jolly Farmer uses three different recipes. Tim Livingston will use two. At min, you want a recipe that is more peat based, with lower fertility for some crops. The other should be higher fertility with compost.

Capillary action – need more air space than you would outside. The more flat and long your tray, the more it will hold water. In little tapered cells, the soil will breathe much better. But with cells, you must ensure that each cell gets hit with the same amount of water.

Soils rich in compost – you want to use the very best compost you have on the farm. Qualities you're looking for: well aged and mature (ingredients must not be recognizable), you want crumbly structure (not gluey), ultimate test": take a hand full of compost and drop it into a glass of water, if the water stays clear, you have good compost, if it turns black, it's not ready. "Reserve the absolute best for making a mixture for transplants". Fungus gnats eat roots… you don't want them in compost. You want a good C:N ratio (not heavy on wood).

Compost mix is a heavier mix, so more structure. But can reduce germination because fertility is high. Can be harder to rewet when dry. Roots tend to be thinner and fall apart more easily.

Peat mixes: more aeration.

pH is 7 or higher… doesn't cause a problem because of amount of compost. Threshold with compost mixes : compost fills air spaces surrounding peat. 50:50 makes it too wet. Upping it to 60:40 actually makes a better mix. Don't want more than 5-10% worm castings. Tomatoes can handle a wetter mix, so can use a higher % of castings.

With peat mix: 10% compost, 15-20% perlite, 5-10% vermiculite, the rest peat. Also need to put in some limestone b/c peat is very acidic. Peat changes from year to year, so need to do a pH test. Must soak in distilled water (saturate soil) for 72 hours to get calcium release and then you do pH. Otherwise your reading will be higher than it ought to be. You want your pH to be between 6 and 6.5 in a mix with compost. Without compost, you want 5.7-6.1.

11 lbs of calcitic lime per cubic yard with worm castings mix. Less than that with compost based mix.

Dolomitic lime gives you Magnesium, too. Calcitic (calcium carbonate) only gives you Ca.

Jolly Farmers's peat mix has 15 ingredients. Only that complicated because 4-6 months needed for tomatoes, so needed better balance and nutrient availability.

Compost mix: compost, peat, iron sulfate (gives green), wetting agent

Use the finest grind of lime you can use. Change the types of lime to give you longer terms of pH buffering. Larger size for long term. Powder for short term.

Wood Ash? Electrical Conductivity can get too high and reduce germination potential

Can you use same mix for seeding as transplanting? They try to only direct seed and only upsize if the cost can be justified: tomatoes, eggplant and peppers grow best in high fert mix but germinate best in a low fert mix. Tomatoes they do in a 4" because they will be spaced out. Peppers in a 2".

With tomatoes, 1st true leaves already determine # of clusters, so best to transplant at that stage.

Don't bury the tomato b/c energy will go into root creation when stem is in soil and more energy will go into foliage development instead of fruit. Plant at the same level (depth) as in pot). Some even leave part of where pot was out of soil to slow down root growth.

Compost can be high in K or salts, especially if not fully finished. K will displace Ca as a cation, so there won't be as much Ca available. Can add protein meals like alfalfa, soy, feather. Use sparingly so that you don't recreate a compost pile in your mix. Put in ahead of time to ensure stability. A stable compost ensures availability of nutrients. "Compost your fertility before you add it to the mix". For liquid fertilizers, not many options other than fish available.

Liquid fertilizers can be costly. You want to have something on hand so you can use it if your plants need it. Takes 3-5 days before nutrients are available after application.

Use fine mix for plug trays. Course mix for pots.

Seed single seed/cell for solanaceae, brassicas and melons.

Can use doubles for allium, basil, corn, cukes and squash. Onions b/c less transplant time, but come harvest there will be some with a flat sides. May also compromise size. Can do onions in a plug for 9-10 weeks if you want to keep single.

Vermiculite is good as a coverer – holds water but lets air in. wouldn't use on herbs. Cover 2 x's the seed depth in cover

As the plant grows, you increase your fluctuations. Start off with an even water and consistent.

They're more sensitive once they germ and that first root comes out. "Light is power, temp is your speed". If too warm, you will get a stretchy plant. If cool enough during short days, you won't get stretching.

Beneficials from Koppert (BioBest too). Better to do earlier than later. With soaps, you run the risk of burning the foliage, so try to refrain.

(*can use onion sets as a trap crop for aphids. Peppers too).

3-4 weeks for melons before transplanting (1-2 true leaves 2nd just coming). 2 weeks for cukes. 1-1.5" cell size. He starts them 1st to 2nd week of May. Planting around 24th May. Start with cukes and squash, then the less vigorous melons.

Brassicas – 5 inches high at transplant. Uses a high compost mix that counteracts the stretchiness from being close together. 3 planting times – early May, mid June and mid July. (done in 144's)

Peppers – transplant out mid June

When they plant tomatoes, they leave in 4" pot until there are flower clusters and maybe even some fruit. Two weeks in plug (288's) and 6 weeks in a pot.

Questions:

Purple colour? Low P (driven by low temp because P in soil is not available)

Growing tomatoes:

They only grow cherry tomatoes under cover. Keeps water off and gives them structure.

Grow indeterminate tomatoes in the field using post every 7 plants with tomato twine. Add another set of string at each foot of growth. Once they get to four clusters, they top them (around mid Aug) b/c you're not going to harvest anything beyond that anyway.

Corn from transplants tends to turn yellow, but they perk back. 1' between plants, rows at ~36"

9:30-10:30 **Keeping greenhouse soils fertile: nutrients, compost and salt**
with Rupert Jannasch, Ironwood Farm

Greenhouse soils tend to have higher nutrient levels (including salts) because they are not leached out by heavy rains or melting snow. Most greenhouses are also operated at a higher plane of nutrition than field soils. The system is "super charged" and small variations in water or nutrient levels can make a big difference to productivity. By contrast, in a Haygrove tunnel, where the plastic is removed each winter, nutrient and salt build-up in the soil rarely occurs because of exposure to precipitation.

Drainage is one of the most important considerations when deciding where to locate a greenhouse. Drainage most influenced by soil texture. Texture is determined by the proportions of sand, silt and clay. Learn to recognize the amount of sand in your soil. Sand tempers the clay and silt content by creating large pore spaces that improve drainage.

At Ironwood Farm we used clay scooped out from digging an irrigation pond and built a pad 3-4 feet high over some poorly drained field soil. One foot of gravelly topsoil was put over the clay base and topped with compost. Not an ideal scenario, but one that provides good drainage and ventilation. The steep banks help shed snow. Even a 6-12 inch pad of gravel or sand under a greenhouse can greatly improve drainage in a high clay soil.

A common soil test, the Mehlich III test, reports nutrients in lbs/acre. It is not reliable in greenhouse soils because nutrient levels will be reported "off the charts" (Vern Grubinger, UVM). The Saturated Media Extract (SME) test reports in part per million (ppm). The SME also tests for electrical conductivity (EC), which is a measure of soluble salts. The higher the EC, the more soluble salts. The NS soil lab at the Harlow Institute offers this test, as do most agricultural soil labs.). Costs range from $20-40 (less for

registered farmers). Ask for the SME test specifically or soil tests specifically designed for greenhouse soils.

The SME test does not report organic matter levels. It reports EC, pH and nutrients, including nitrates. Optimal amounts vary depending on crop. The test reports provide recommended ranges for some crops. The real proof is tissue testing, which shows the amount of nutrients that made it into the plant. Optimal tissue nutrient ranges can be found on the Internet, but it is a good idea to compare two or three sources for the same crop.

Note that rock phosphate is poorly soluble whereas soft colloidal phosphate is more readily available for uptake by plants.

To take a soil sample, take a composite samples (perhaps 15 samples from a 5 x 100 ft bed mixed in a bucket. Borrow a soil probe or improvise by taking a 1 inch soil slice with a spade, 6 inches deep, and cutting a one inch section from the side of the slice.

Plant vs. animal compost. Animal compost may have higher in salts levels. In the book "Soil Fertility" biodynamic agronomist Pfeiffer values plant-based compost for market gardening.

NutriWave, a common brand of composted chicken manure, should not be confused with true compost. It is rich in nutrients (NPK), but not biologically active. Does not provide the same benefits as the rich, dark, friable material that almost looks like earthworm castings (high organic matter, a balanced nutrient content and biologically active). An entire workshop could be devoted to discussing compost quality.

Animal manures typically contain many nutrients in salt form. Salts are everywhere because each time an acid reacts with a base a salt forms. Exposing compost piles to rain and snow helps leach away excess salts, but can also leach large quantities of potassium. High salt levels restrict germination and root growth, burn foliage and can reduce flowering. Salts are not always harmful. Plants take up many nutrients in salt form.

Salts levels are measured by testing for electrical conductivity. On Ironwood farm, EC jumped from 2.5 in 2006 (shortly after greenhouse was built) up to 7.0 four years later (optimum range is 3-4). Are the high salt levels due to high amounts of bicarbonate in the irrigation water or because of using manure-based compost or because of limiting water use and irrigating with drip lines.

At Ironwood Farm we haven't applied as much water as recommended in a greenhouse to avoid moisture issues (leaf diseases) and problem weeds like chickweed (seems to thrive in wet). Less irrigation produces a better tasting tomato (even if some yield is sacrificed). By using drip lines (and animal-based compost) the result was high salt levels. By contrast, a neighbour, Norbert Kungl, has watered much more heavily with sprinklers over the years (partly because he grew more greens) and had a major chickweed problem. At Ironwood the chickweed became established when Jannasch began watering more heavily – in part to wash out excess salts.

Note: By limiting water, you can induce blossom end rot because the Ca/Mg ratio is altered.

How to get rid of salts? Leach them out artificially they way conventional greenhouse growers do. Just letting a sprinkler go wide open will do. Tricky in confined areas when dealing with a bed system in the greenhouse. Perhaps a soaker hose would work. Drip lines can be part of the problem because the water flow is so low.

Not using compost means reliance on liquid fertilizers and you're losing out on biological activity – the driver behind organic agriculture.

11:00-12:00 **Grafting tomatoes and cucurbits**
with Dr. Cary Rivard, Kansas State University

Soil borne diseases are a challenge for growing in high tunnels. Grafted plants are a good way to control for soil borne diseases and the plants can also be marketable to home gardeners.

Tomatoes were first grafted to manage bacterial wilt in 1950's in Asia. Grafting has been done for a long time all over the world, and was popularized in Japan and Korea (melons and cucumbers are commonly grafted crops).

There are a number of different methods for grafting vegetable crops. For tomatoes, the tube grafting technique is generally used but cleft grafting works well too if you have rootstock (bottom) and scion (top, fruiting portion) that are different sizes. If you have 100-200 tomatoes, then tube grafting is most practical. With cucumbers, the tongue approach method of grafting is most common.

Choose a rootstock that is resistant to disease, less susceptible to cold stress, and will yield well. There are cucumber varieties that are resistant to wilt. Intergeneric grafting can be done with cucumbers (2 different species), which will confer disease resistance.

In tomato grafting, the heirloom varieties are used as scions. Determinate red varieties are really good at partitioning energy from rootstock into yield. Rootstocks used can be a cross between wild and cultured species (interspecific hybrid rootstocks). These are very vigorous and resistant to diseases.

The main benefit of grafting is the increased protection against vascular diseases. Rootstocks are more efficient at mining nutrients, which translates into higher yield of your scion variety. A good starting point for new growers would be with cherry tomatoes as scion because they're vigorous and grow well under poor conditions.

For rootstocks, Beaufort and Maxifort are most commonly used. Beaufort is used for grafting heirloom varieties because Maxifort grows too vigorously for them. Trooper gives good yield increases and isn't over vigorous for heirlooms.

Some of the work Cary has done was with CEFS (Centre for Environmental Farming Systems). A research trial he worked on has demonstrated yield of grafted tomatoes was higher in both high tunnel and open-field environments. Beaufort was better for growing indeterminate heirloom scion.

Cedar Meadow Farm (SARE) was a farm facing challenges with Verticilliium Wilt, which is common in cooler climates. This is a wilt that moves in slowly into the root system and strangles the plant. It may not be visible until later in the season; V-shaped lesions are telltale. "Race 2" is prevalent. It is generally managed via fumigation. The goal of grafting research was to try to find a rootstock that is vigorous and might do well against slow verticilliium wilt. Results showed that grafting provides a viable alternative to fumigation. Spacing of 24" provided optimal plant spacing for grafted plants.

To summarize the benefits of grafting, Cary stated that grafting provides a site-specific management tool for soilborne disease, but that diagnosis and rootstock selection are critical. Know which diseases you are susceptible to. No rootstock is resistant to all diseases. They are specific.

The use of rootstocks may increase yield through added vigour and nutrient uptake. Although there's an increased cost, cultural management (spacing, fertility) may reduce economic constraints.

Cary then went on to outline the methods used to graft tomatoes using the Tube grafting technique. Seedlings are grafted at the 2-4 leaf stage. Tube grafting of tomatoes is much easier than cleft or approach method if >200 plants. An average grower can do 150-200 plants/hour with tube grafting. You can create unique "double headed" plants with two different scions.

It can cost 46-74 more cents to produce a grafted plant. Rootstock seed cost is much higher. There are also indirect additional costs – you are growing two crops, so double the amount of all resources required.

Uniformity of your seedlings is key to grafting success. You need a good uniform rootstock and scion crop to get them to match up. They'll stagger the seeding because sometimes rootstocks are slower or faster growing than the scion. If seedling emerges within a 48 hour window, this is a good average. It is preferable to have the scion too small for the rootstock than too big, as the rootstock can be put in cooler environment to slow down growth.

Uniformity dictates the speed and ease that you are able to graft later. At the 2-4 leaf stage, be ready to graft because it can be a huge challenge if they're too big.

He germinates tomatoes in a seedling or plug tray and then transplants into 50-cell nursery tray. End up with a more uniform crop because can get rid of smaller or larger ones. For the seedling mix, he would mix in 30-40% sand into peat moss to get better drainage.

Before grafting, make sure plants aren't water or nutrient stressed. Make sure work area is clean (use xeritol or 10% bleach) to avoid disease. Clean clips with bleach, but rinse.

Grafting shouldn't be done when the plant is transpiring heavily during the day. If daytime, put the plants into shade house for a few hours so scion is turgid. He does grafting at night because less likely to be water stressed and not transpiring.

Cut rootstocks lower than cotyledons to reduce the number of suckers that come off. Silicon clip slides right over the rootstock. The angle of cut doesn't matter. Make the plane of the cut perpendicular to the clip. Ensure good contact between scion and rootstock so vascular tissue can reconnect.

After the graft is done, put the plants into a healing chamber where humidity is as high as possible and light is cut out. Over the next 7 to 10 days, gradually add light and bring humidity back down. The healing chamber actually keeps the scion alive for 7-10 days before the connection to the rootstock is complete. Add enough humidity to ensure the plant doesn't transpire, wilt and die.

Regulating the humidity is critical. Small chambers keep high humidity. You can use a cool water vaporizer or passive humidifier. You must keep healing chamber out of direct sun. Plastic can be used to keep humidity in. Edema may be a problem when relative humidity is too high. It can be quickly solved once humidity is reduced - just watch for it.

Shade cloth is needed over top of the chamber to keep light out. Make the chamber as dark as you can for first 48h. You must harden off the transplants after being in the humidity chamber. Gradually reintroduce light. Overhead watering good for cooling down plants; water the plastic around plant cell, not the cell itself.

You want to keep scion as high off of soil as possible because you don't want roots coming from that part. Strings can be used to keep scion from laying down and rooting.

12:00-12:30 **Low cost tunnels and gutter connected cold frames**
with Paul Bourque, OCTA Greenhouses

OCTA Greenhouses is the largest greenhouse manufacturer in Canada. Paul Bourque has been working in the industry for a long time and has acquired a lot of knowledge. We were fortunate to have him come and share with us!

Paul gave us numerous tips:

- Shelter tunnel houses are not designed to be covered in the winter
- The less steel used, the lower the cost
- A greenhouse can be left covered in winter
- There are two main engineering forces to consider: wind load (sideward forces) and snow load (downward forces)
- The closer the arches, the stronger the structure.
- Paul told us about the "Ova tech 3" which is more structurally sound than the steel conventionally used in greenhouses. Oval steel is stronger than square.
- There are three options for ventilation: open end walls, roll up sides, ventilation fan. A roll-up skirt is $700-$800 per side. A ventilation fan system can cost up to $5000.
- "Anchoring down that greenhouse is fundamental." Anchoring has the highest cost in terms of material and time/labour required, however you will get the best return on that investment. Do not skimp on this important step in greenhouse construction!

- Do not open up your greenhouse under really high winds: It will lift right up!
- The best tip Paul has up his sleeve: Anyone who owns a greenhouse should have a hockey stick with a knife on it kept on hand. In a wind storm, cut that poly off and let it go! Literally cut your losses. The plastic is stronger than the steel structure. If you don't cut the plastic, you are risking losing the whole thing.
- Paul really understands the value of gatherings like these where producers can share their experiences with each other. He says the best part is the camaraderie that develops with those doing the same work you are:

> *"If you can call someone up at 10 am, in the middle of a windstorm when you think you're about to lose your greenhouse, so you can commiserate and get advice, then you've gotten out of this conference what you should"*

1:15-2:15 C**ontrolling the impact of wind and water on greenhouse structures and the option of moveable greenhouses**
with Norm Eygenraam, Multi-Shelter Solutions

Norm generously shared his knowledge with us from his extensive experience in helping people purchase greenhouse structures AND as a pilot. Yes, the two ARE related.

A greenhouse's structural design is remarkably similar to that of an airplane (e.g. the engineering phenomenon of "uplift"). This design is wonderful if you have an airplane that you want to get off the ground; but poses a challenge for the greenhouse grower who would much prefer to keep the greenhouse grounded and secure during a windstorm. Norm provided the audience with many useful tips for ensuring your greenhouse is secure.

Do not underestimate the force of your endcovers. The cover adds tremendous bracing. However, on a 30 foot x70 foot greenhouse with 3 foot spacing between the arches, the surface area of arches is greater than that of the endwall. "The more pieces you have attached, the more you'll have to pull". There is no such thing as too many anchors (a board right below grade on each side gives the greenhouse structure more anchoring). Do it right the first time!

If there is any wiggle room anywhere, the wind will work on that point until it is destroyed. Norm doesn't like fitted tarps because the radius doesn't match up. There will be wrinkles and eventually the tarp will wear in the wind. Wire lock can be used to remedy some situations when there are wrinkles. Always pull 90° to the wrinkle to get rid of it.

Four forces are applied to a greenhouse: down force, uplift, lateral force and end force. Down force is snow, the remaining three are wind. All of these forces are creating a compression load (when squeezed) and a tensile load (when stretched). These two are working against each other all the time. Greenhouse structures do not have predictable loads. The dimensions in a greenhouse are so variable throughout the structure.

With downward force, remember that an even snow load is much more stable than an uneven one. The greenhouse can withstand a lot more than with an uneven snow load. Remember this when you are clearing the snow off of your greenhouse. Never clear all of one side first because you are creating an uneven snow load. Also, remember that rain can greatly increase the magnitude of downward force. Ten inches of snow could become a problem with rain. If it started raining, the weight could easily triple in 20 minutes. A trick for removing snow off the top of your greenhouse: a 3" piece of 1x4 secured at 90° to an 8 foot 2x4. Use this to give the snow a quick bump and slide the snow off. Caution! If you notice that any part of your greenhouse is slightly twisted (not uniform) while assessing snow damage, do not enter the structure.

When you are working with multiple structures, there are many variables to consider in spacing. An important consideration is the size of the snow removal equipment. Typically 8 feet spacing between your greenhouses is OK (but make sure you don't have a 10 foot snow blade!)

Tips from Norm for increasing the structural stability of your greenhouse:

- Putting a cable across will give a lot of tensile strength.
- With a long arch, no matter how tight the plastic is put on there, you won't be able to remove the flutter. With a long arch, you are adding more lateral force and downward force and are therefore compromising the steel strength.
- The shorter the straight part before you get your curve, the easier to get the plastic tight.
- Install a vertical tie from the cross bar to keep the cross tine from bowing. This adds a lot of rigidity.
- Uplift is often overlooked. There are 250 lbs of uplift, 275 lbs of lateral force and 570 lbs of downward force per linear foot.
- Putting a greenhouse behind another building does not protect it, it actually worsens the load.
- When you raise the building 17°, you're actually getting double the load.
- If you go from a 20 foot to 30 foot long greenhouse (so 50% bigger), you are actually doubling the load. Also a 20 foot long greenhouse is 10 feet high, and a 30 foot long greenhouse is 15 feet high. This is only 50% higher, but the lateral force is actually doubled. This works the other way too! For example, a 1x3 side bar is double the strength of 1x2.
- The required holding power on individual posts is becoming greater. Torrential rains can weaken anchoring. Set corner anchor posts into concrete or screw in anchors to reinforce structure.
- To help control end force, use rows of purlins and make sure they are all ultimately braced to the ground. Curved purlins cause problems with compression / tension dynamics. Replace solid rods with cables that pull to the end. This is much more predictable than alternating between compression and tension. However, do not anchor to the base of the last arch.
- Keeping established anchors is not desirable as they are easily damaged by equipment etc and they are hard to re-establish once damaged.

Norm showed us a new greenhouse design: Geodesic greenhouses! These igloo shaped greenhouses mean that there is no need to brace and they eliminate the airplane effect of uplift. A 30 foot geodesic greenhouse costs about $2200. The whole structure is all ultimately attached to a circular round piece.

If you choose to do a geodesic greenhouse, Norm says you should have previous experience with plastic installation. Also, the installation of doors could be complicated.

Many farmers are interested in moveable greenhouse structures because they help to avoid the problems of supercharged soils and disease cycles. There are many questions which the farmer should determine the answers to first: How often will you need to move the structure? How far will you have to move it? What direction will you be moving it? Is it flat? Are you moving off a crop onto vacant land; or the other way; or both? if you're moving something (like tree seedlings) twice a day, you would want wheels, but if only twice per year, then you would want it on a more substantial beam.

When moving a greenhouse, and pulling with a tractor from the front onto open land, the front will want to compress while the back end will want to become wider. In order to move the greenhouse without collapsing the front, you need to have a comealong at each front corner and tug in a straight line.

2:15-3:15 **Inexpensive season extension options**
with David Greenberg, Red Fox Farm

There are two different approaches to greenhouse growing, each with different production requirements for timing and quality:

1. As a specialty in and of itself. This would be nurseries that sell bedding plants, hanging baskets and other ornamentals for the home gardener. This kind of greenhouse production requires a very highly controlled environment.

2. To enhance your primary occupation: farming! This enhances the vegetables, herbs etc that you already have growing on your farm so that you can have a longer growing season and healthier plants.

Some questions which a farmer would want to consider before investing in a greenhouse structure:

Can you get enough of the benefit from controlled greenhouses to justify the costs? How much would your farm benefit of season extension? How do you get enough season extension to make a living? Are you knowledgeable enough about greenhouse construction to do it right? Not everyone has the technical skill required… know your personal limitations! Greenhouses have many parts and each require skills, money and time.

On David's farm, they do not use year round greenhouses. Instead he has developed other inexpensive season extension strategies. He recognizes that this is what works for him and would not be used by everyone. He also knows that they do not have it perfected and are learning more and more every year.

David likes the "Hanley" hoop house, which does away with the need for baseboards and purlins. He has slightly modified the Hanley design to suit his needs. The basic construction involved in building his hoop houses requires very little skill, money and time.

Here is the basic process he uses:

David uses 15mm diameter rebar to secure the structure. He pounds these into the ground at the desired intervals of where he'll want the hoops. He uses 1" galvanized tubes for his hoop houses. They cost him $28/hoop delivered from Russell Meadows in Lakeside Industrial Park. He uses the "hoop bender" to bend the galvanized tubes. He slides the hoops over the rebar and uses a washer (which acts like a cam-lock). He locks them onto white ¼" polyester rope. The plastic is laid over the structure and is only attached to the ropes.

At the ends, he gathers up the plastic and uses two pieces of snow fence post pounded into the ground parallel. He then ties the plastic into a knot, slides the knot behind the posts and uses string to tie it around.

Additional technical information:

- Hanley hoop houses use wiggle wire.
- Hoop houses do not require perlins, so water won't pool and pull the plastic.
- David uses rope just on the end hoop to keep it from leaning in.
- Rope is also used on outside of plastic attached to lanyards. The rope is used to zigzag between the arches. Rope is effective instead of using wiggle wire (wiggle wire takes long to install and is expensive)
- With the first major snowstorm (usually in December), David pulls the plastic off (when the storm first starts!) He just leaves the plastic there on the ground for the winter. In early March, he recovers it.

For more information on the net, google "Todd Hanley Hoop house". Also, www.heliotrust.org (Ecology Action Centre) has more information on hoop houses.

Questions:

1. Why hoop houses instead of established greenhouses?

A: Largely to overcome the supercharged soil dynamics created in a greenhouse environment. Hoop houses can easily be taken down in a day and moved onto cover cropped land. And you are still getting most of the same benefits of an established greenhouse. For example, David can still plant tomatoes out May 1st. In September, he plants salad mixes in his hoop houses. He is able to get ~3 crops out of his hoop houses per year.

2. What holds it down?

The radius of the bender makes a hoop that is 18' across and the house is 17', so the excess provides stability in the ground. Also, the tube is affixed onto the rebar. The rebar is banged into the ground in such a way that it provides friction for holding the tube.

3. What width of plastic do you use?

A: If you had 24' long hoops, you'd use 26' wide plastic. 25' would get you to the edge, but with wrinkling and not a lot of extra to spare. So ideally, you want one foot extra for each side. This also allows you to shovel dirt onto the edge on the side with wind.

3. What kind of material do you use for the hoops?

A: Norm Eygenraam suggested using a galvanized 1"x2" preformed tube (instead of 1" and bending it yourself).

4. Could you use PVC?

A: PVC is more expensive, not as strong, doesn't last as long, leeches out chemicals and doesn't react well with plastic.

5. What do you do for ventilation?

A: The hoop house is 7.5' high and they ventilate 4' on each side, so the structure is well ventilated.

3:15-3:30 Wrap-up

What workshops would you like to see in the future?

The audience expressed interest in having workshops on pest management in the greenhouse. Of particular interest is the use of beneficial insects such as predatory beetles and parasitoid wasps.

The farmers present were also interested in a workshop presenting ways of increasing energy efficiency in their greenhouses.