United States Department of Agriculture

Controlling the High Tunnel Environment

Natural Resources Conservation Service

Figure 1. Grower venting his high tunnel by rolling up the side

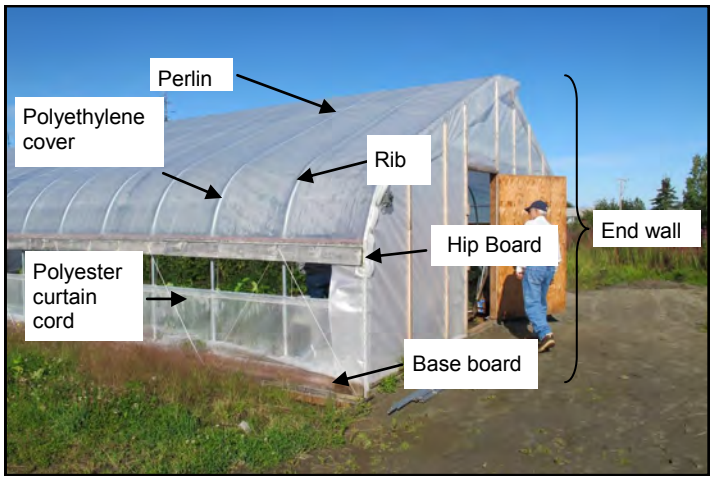

Figure 2. Gothic high tunnel with components labeled

Managing Temperature

High tunnels benefit growers by extending the season in which they can grow crops. They do this by taking advantage of the "greenhouse effect." With this benefit however, comes the need to balance the heat load with cooling so plants do not become stressed.

For instance, tomatoes grow best at 70 to 75°F and have a maximum air temperature of 85°F. Temperatures much higher than 85°F day/75°F night can stress tomato cultivars and result in flower abortion, pollen sterility and ripening disorders (Table 1). In addition to the increased heat load on plants, warm air holds more moisture and disease problems can occur above 85 percent relative humidity (RH). The grower must manage the high tunnel environment to provide optimal growing conditions for their crops while minimizing disease incidence.

Site Selection

Site selection for your high tunnel depends on a number of factors, not the least of which is the angle of the sun. You want to maximize the amount of sunlight plants get. At the same time, many say you should orient your high tunnel so that the end wall faces the winter winds. In some Alaskan locales, these two are not the same. High tunnel manufacturers however, suggest that the structure should be oriented in order to capture the most sunlight in winter. For areas north of 40° latitude (all of Alaska) that means the ridgeline will run east to west.

Shading

Shade plays an important part in site selection because it limits the amount of light delivered to your high tunnel. The rule of thumb is high tunnels should be built at a distance twice as far from an obstacle as is the height of that obstacle. For example, if building two high tunnels next to one another and each high tunnel is 12 feet tall, then high tunnel B (HT B) has to be at least 24 feet from HT A. This applies to other obstacles like trees as well (Fig.3).

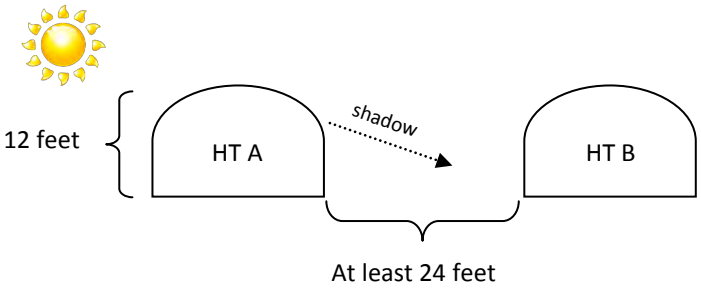

Figure 3. Shadow affects site selection

Soil Drainage

Try not to place your high tunnel in an area of your land where the water table is known to be close to the surface, where you have an impermeable soil layer, or where other factors might cause water to puddle in your high tunnel. Watching your tomatoes rot or having to trump through mud to weed your crops is not fun. Crops benefit from increased microbial activity and most beneficial microbes will not work if the soil is saturated and without air.

Site Selection: Accessibility

One characterization of a high tunnel is that it be tall enough in the mid-ridge to drive a tractor into (albeit smaller tractor). High tunnels are designed to be accessible, so take advantage of this. Do not locate them where you cannot get in and around easily.

Table 1. Crops and their optimum temperature for different growth stages

Crop	Growth stage	Optimum temperature (°F)	Maximum temperature (°F)	Threshold temperature for venting (°F)
Tomato	*Transplant-flowering*	70-75°F	85°F	75°F
	Flowering-harvest	70-75°F	85°F	65°F
Pepper	*Transplant-flowering*	70-80°F	85°F	75°F
	Flowering-harvest	70-80°F	90°F	75°F
Cucumber	*Transplant-flowering*	70-85°F	90°F	80°F
	Flowering-harvest	75-85°F	90°F	80°F
Leafy Greens	Seeding-harvest	60-65°F	75°F	55°F

Ventilation

Ventilation in a high tunnel serves a dual purpose:

- Temperature control (cooling)
- Humidity control

When humans are out in the sun our skin gets hot so we perspire through our pores and this serves to cool us off. We have all felt the coolness when we are perspiring and a wind blows across our skin. The same thing happens to plants. In bright sun, plant surfaces heat up and they transpire through their stomates (holes in leaf surfaces analogous to pores in human skin). The other side of this phenomenon is that as plants open their stomates to transpire they also take in carbon dioxide (one of the raw components of photosynthesis). If plants get too hot they shut down their stomates to stop transpiring (also shutting off the intake of carbon dioxide). If the heat load is allowed to continue, plants grow poorly and can die.

Venting the high tunnel serves to prevent this heat load on plants. Keep in mind however, different crop species can tolerate higher temperatures than others. The table above presents the optimum temperatures for our more valuable high tunnel crops. Immediately apparent is that leafy greens should be grown sooner or later in the year than cucumbers because of their lower temperature requirements.

The other purpose for venting a high tunnel is to reduce relative humidity. This is important because the higher the relative humidity the more chance for plant diseases to become a problem.

Methods of Ventilation

Active ventilation refers to methods that use a continual supply of electricity to monitor and control ventilation. These methods are usually wired in to a thermostat mounted somewhere in the middle of the high tunnel (Figs. 4,5).

Figure 4. High tunnel with active venting fan

Figure 5. Thermostats mounted in a greenhouse control ventilation by opening and closing vents and controlling fans

Ventilation

Passive ventilation refers to methods that rely on convective air currents or the natural tendency of warm air to rise and cool air to sink; this in addition to taking advantage of prevailing winds. The thermostats (Fig. 5) operate fans and louvered vents that actively draw in air from down low and expel it through ridge vents or end wall vents (Figs. 6, 7). The solar powered vent opener (Fig. 8) uses paraffin which expands when warm and contracts when cooled to open an end wall or ridge vent (Figs. 6, 7). An easy strategy you can employ is using very large end wall doors (Fig. 9).

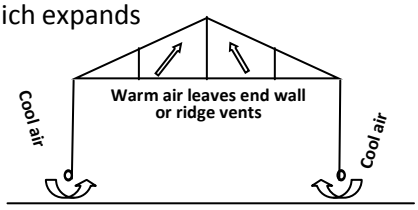

Figure 6. Diagram of desired air movement

Figure 7. Vents mounted at top of end wall with solar power

Figure 8. Solar powered vent opener. Some of these can handle

Figure 9. Another way to vent a high tunnel is to install a large door in the end wall. This one is an insulated roll up door

Circulation

Another way to enhance air movement within a high tunnel is the use of circulating fans (Fig. 10). Circulating fans serve to reduce disease incidence by keeping any humidity from settling over the plant leaves. This is a very important concept if your crop density is high. The set-up can be as elaborate as being wired in to your thermostat or as simple as a number of rummage store stand fans. You are just looking to keep air moving.

Figure 10. Circulating fan

The subject of high tunnel ventilation can seem quite complex and overwhelming. There are entire college degrees based around the physics of what constitutes proper ventilation as well as heating in a high tunnel. Your needs will change and as you gain experience you will learn to adjust your ventilation to the needs of your changing crop choices.

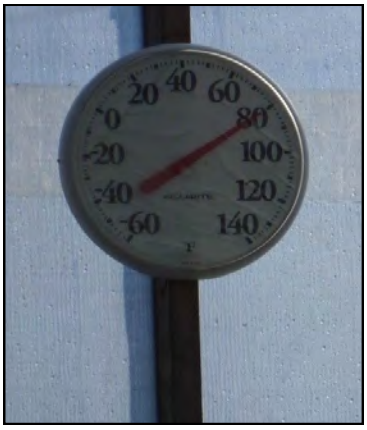
Figure 11 . A big faced thermometer mounted up on the rib of a high tunnel

For a nominal fee you can get four or five big faced thermometers (Fig. 11). You could mount one high up in the midridge of your high tunnel and another down lower where cool air is likely to be. A third can be mounted just outside the high tunnel so you get an idea of the outside air temperature. These thermometers are all easy to see from a distance, they don't have to be too accurate (within a few degrees), and you can monitor them daily.

Another crucial investment is a "hygrometer" (instrument used for measuring the moisture content in the air). You can find a hygrometer usually packaged in a case with an indoor/outdoor thermometer (Fig. 12) . If you are adventuresome you may find the whole package bundled up as (what horticulturists call) a max/min hygro-thermometer. This valuable instrument reads relative humidity, the indoor/outdoor current temperature and the minimum/maximum temperature that has occurred during a predetermined time. These are usually sold by greenhouse and garden suppliers.

Figure 12. A relatively inexpensive indoor/ outdoor hygrothermometer.

Irrigation

Outfitting of High Tunnels for Irrigation

A high tunnel gives the grower the ultimate control over success or failure. With this tremendous power also comes tremendous responsibility. Plants use water for photosynthesis and to cool off. Two of the most important equations to keep in mind are:

photosynthesis + transpiration > water uptake by roots = reduced yield & plant death

water delivery > photosynthesis + transpiration = disease, leaching, no oxygen

Irrigation is a balancing act between too much and too little. Most literature by high tunnel experts suggest drip irrigation is the preferred method of water delivery. One of the main reasons is to keep water off the leaves to decrease disease. Overhead systems, if not monitored closely can:

- increase relative humidity
- Increase disease pressure

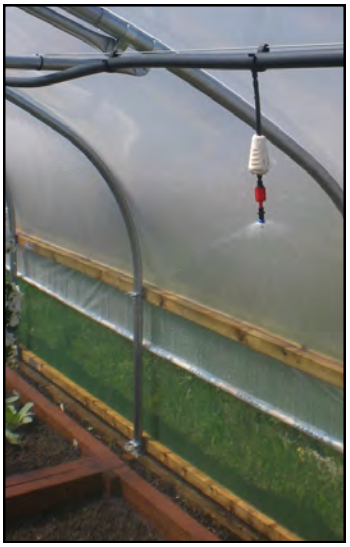

Figure 13. Overhead sprinkler in a high tunnel

The conscientious grower can use overhead irrigation as long as they vent the tunnel to reduce wet leaf surfaces (Fig 13).

Advantages of Drip Irrigation

- Uses water more efficiently.
- Uses less energy.
- Is easily automated.
- Reduces pest (disease problems).
- Makes weed management and tillage easier.
- Applies fertilizer more accurately (if fertigating with water soluble fertilizer).
- Can provide warmer water.
- Is versatile (can be easily added to or reduced).

Disadvantages of Drip Irrigation

- Spacing of emitters has to match or be close to plant spacing.
- Small emitters clog easily (hard water, dirt, fertilizer). (Just as you have your soil tested, have your water tested for its mineral content.)

Drip Irrigation Needs

- A source of water whether it is off your house well or you dig a well for your agricultural operation.
- A way to shut your water source off.
- A backflow prevention device between your water source and your timer.
- Some means of timing your application. These can be as simple as a battery driven one zone timer you buy from a local box store to an electrical plumbed timer with many zones, all running at different application rates.
- Pressure regulator - Many water sources run at 60 psi, drip systems run at around 10 psi.
- A water filter.

A typical simple drip irrigation control system looks like the representation in Figure 14.

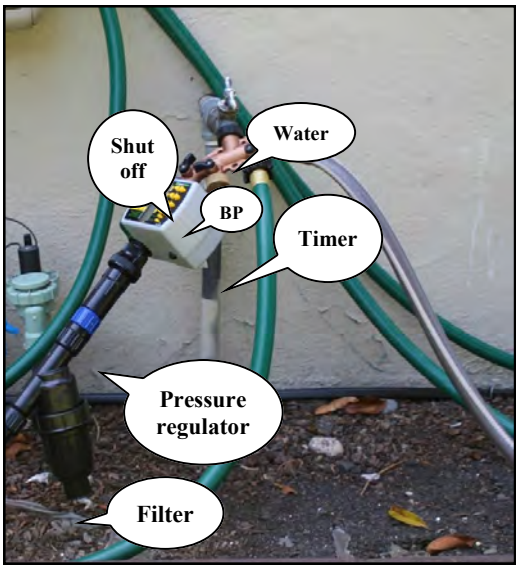

Figure 14. Schematic of lay-out of a drip irrigation system. Usually a backflow preventer is located between water source and timer (BP)

What is an emitter? Simply put, an emitter is a device that gives or sends something out, in this case, water. There are basically two types.

- Those that allow water to drip or seek onto the root zone (drip irrigators, Fig. 15).
- Those that direct water into the air much like a miniature sprinkler head (micro-sprinkler, Fig 16).

Emitters come in different sizes and configurations designed to provide a specific volume of water over a known time.

Micro-sprinklers work in much the same way except they come in different patterns, from a complete circle to a half moon to a number of pie shapes.

Irrigation

Figure 15. Inline drip emitter

Figure 16. Microirrigation sprinkler

Figure 17 shows drip irrigation tape running along the soil surface next to a plant. There are a variety of tapes with built in emitter holes of various spacing's depending on what plant you are growing and your application needs. This example shows two emitters (Fig. 17).

Figure 17. Drip irrigation tape. This tape is designed to drip water in a precise place at a precise rate based on plant spacing

The overarching goal of irrigation is to get an appropriate amount of moisture into the root zone of your crops at the appropriate time. The amount of moisture that gets to roots is affected by:

- Soil texture - see Fig. 18.
- Irrigation quantity
- Irrigation frequency
- Crop rooting - some plants root shallow, some deep.

The high tunnel operator has to determine these pieces to the puzzle and act appropriately with the knowledge that these factors will change from week to week. This is because as plants mature, rooting depth changes and heat load changes on a larger leaf surface.

The following illustration (Fig. 18) speaks volumes if you know what to look for. Clay type soils are a rarity in Alaska but we are familiar with loams and sandy soils.

- Water travels downward in sandy soils very quickly.
- Sandy soil is not good for shallow rooted plants (baby greens).
- Newly seeded plants in a sandy soil will need to be watered more often (water just does not stay in the upper zone very long).
- As plants mature the operator can actually influence rooting by "pulsing irrigation" (decreasing water frequency but increasing water amount).

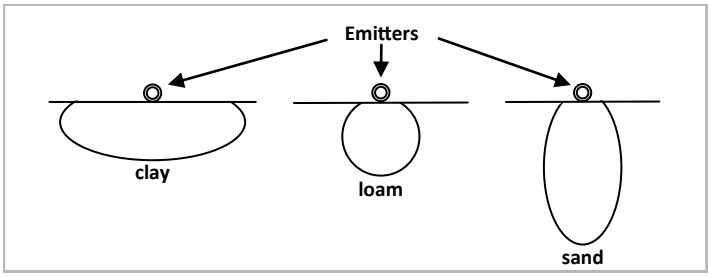

Figure 18. Typical soil wetting patterns from drip irrigation with different soil textures.

Monitoring Soil Moisture

The most foolproof method the operator can use to make sure their plants are getting the moisture they need is to monitor it. There are a number of ways to do this. An investment in quality soil monitoring equipment will pay off in the long run.

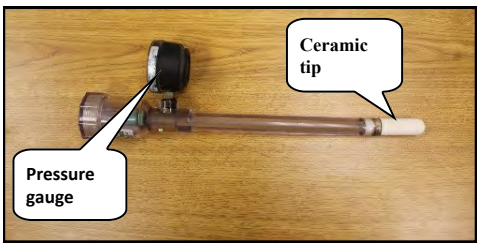

Figure 19. Soil tensiometers come in different lengths

Figure 19 illustrates a tensiometer. It essentially acts like a root and as the soil dries out, it exerts suction on water in the tube. The gauge reads this tension between the tube and the drying soil. Tensiometers are manufactured in different lengths so that the operator can monitor soil moisture at different soil depths to correspond to different root depths.

Other ways to monitor soil moisture are:

- Touch (NRCS's "Feel and Appearance" estimation).
- An inexpensive soil moisture meter

Heating

Figure 20. A high tunnel during the snow season, which, in Alaska, could mean anytime from September through the second week of May

High tunnel heating in Alaska, is a subject where we come face to face with challenges not found in the lower 48 states. It stays colder here than most places in the lower 48 states.

It helps to define what Seasonal High Tunnels were initially designed to be used for. The USDA-NRCS High Tunnel Initiative is designed to "assist producers to extend the growing season for high value crops in an environmentally safe manner."

Is Bigger Better?

A larger high tunnel is less subject to rapid fluctuations in temperature. The larger air mass takes longer to heat up, but is also slower to cool down than a small air mass. This phenomenon is also true of the larger soil mass in a bigger high tunnel.

Another benefit of larger high tunnels is that because space close to a cold wall is normally sacrificed, that area ends up being less of the total space than in a small high tunnel

Big or small, what measures can the high tunnel grower in Alaska undertake in order to extend their season as long as our latitude allows.

Nonrenewable Source Heating

These heating techniques involve methods requiring some kind of mechanical heating device powered by a nonrenewable energy source. This can be oil, propane or natural gas and can include installing in-ground flexible tubes that circulate hot water (Fig. 21) or the use of soil warming electric cables.

Figure 21. In-ground water supply piping system that circulates hot water to heat soil

Figure 22. Propane heater

Figure 23. Gas fired unit heater

Figure 24. A passive heating system that uses black barrels and water

Above ground heating can include a radiant heat propane heater (Fig. 22). This unit can be moved around to different parts of the high tunnel.

The gas fired unit shown in Fig. 23 is mounted to the high tunnel end wall and has a fan that directs heat from the unit. This unit is usually controlled by a thermostatic device as we saw in Fig. 5.

If the grower is going to invest in heating their high tunnel it helps to have circulating fans (Fig. 10).

Renewable Source Heating

There are several ways the grower can heat their high tunnel in a renewable way:

- Passive solar thermal is where the grower takes advantage of site selection and the basic principles of high tunnels. Growers will rely on the fact that water heats up and retains heat longer (Fig. 24).
- Active solar thermal is where the grower uses air tubes and water tubes in a heat exchange capacity.
- A geothermal system uses a heat pump and tubing that runs beneath the soil frost zone to heat when it is cold and cool when it is warm.

Heating

Heat Retention

High tunnels are meant to extend the season and so the grower must find a way to keep what heat they have in the high tunnel from escaping at night for those two or three weeks at the beginning and end of the season.

This is where thermal blankets, thermal curtains, plastic mulch, row cover and low tunnels can be a help. There are a number of fabric manufacturers, and inventive ways of retaining the heat high tunnels build up during the day.

- Thermal blankets are a lightweight closed celled insulating material that goes over plants at night to retain heat.
- A thermal curtain is a fabric sheet and support system that is pulled over the high tunnel growing area at night to reduce heat loss. They are made of clear or aluminized polyester fabric
- Plastic mulch is plastic that is laid down in bed preparation and planted through. The most significant value in plastic mulch is soil warming, followed by weed suppression. Plastic mulch is manufactured in black, clear, and a variety of special colors. Clear plastic allows more light in, but is not as good at suppressing weed growth. You can lay plastic mulch by hand (Fig. 25) or you can invest in a tractor mounted mulch layer (provided you have a short tractor, Fig. 26).

Figure 25 . Installation of plastic mulch in a high tunnel

Figure 26. Tractor mounted mulch layer

- Row covers are manufactured with materials like: perforated plastic, spunbonded polyester, spunbonded polypropylene, and polyvinyl alcohol. They are rated based on the amount of light that penetrates the material and the amount of added frost protection in degrees Fahrenheit.

There are few rules about which one is best. It depends on the growers needs. Row covers can just be draped over a crop and this is called a “Floating Row Cover” (Fig. 27) or it can be draped over metal or plastic hoops into what is know as a “low tunnel.” So the grower can have a series of low tunnels within the high tunnel (Fig. 28).

Figure 27. Floating row cover in high tunnel

Figure 28. Low tunnels in a high tunnel

There are so many options a grower has to choose from that selecting one can seem like a daunting task. It may seem like a person has to be an expert in the physics of venting, irrigation and heating. There are two overarching and comforting thoughts though:

- There is no right or wrong way of accomplishing tasks in a high tunnel. Follow USDA-NRCS guidelines and tailor your high tunnel for your needs.
- There are USDA-NRCS experts and lots of background literature to rely upon when it comes to venting, irrigation, and heating.

Natural Resources Conservation Service
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