Adapting to low light/low temperature conditions using high-tunnel structures in Revelstoke, British Columbia

okanagan college

Acknowledgments

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Terra Park[1], Rob Jay[1], Andrew Perkins[2], Brian May[3] and Michael Mitsch[3]

[1] Owner, Terra Firma Farms, Revelstoke, [2]Professor, Faculty of Geography, SFU, Burnaby, [3]Professor, Faculty of Science, Okanagan College, Salmon Arm

Introduction

This project was motivated by the need for local, low input/low cost, secure production of food in regions of the province that are isolated, and which may have difficulty obtaining fresh fruits and vegetables at key times of the year when growing conditions are limited. The interior of British Columbia, such as the area surrounding Revelstoke, offers an ideal environment to initiate studies such as this due to seasonal travel/delivery issues, and sensitivity to alterations in temperature and sunlight exposure. Lettuce is a low temperature, low light crop and its perishable nature and limited shelf life make it particularly attractive to cultivate in locations where seasonal access and delivery may be an issue. Production of lettuce and other salad greens could give a competitive advantage to local producers who can satisfy local demand. In addition to these prevailing conditions, climate predictions anticipate that as global temperatures rise, snow fall and accumulation in this region will likely be reduced, to be replaced with increased rainfall and accompanying cloud cover[1]. The combination of these effects over the next 30 to 50 years could have very serious implications for the agricultural opportunities for regions such as the B.C. interior. As environmental and climate conditions change, it is important to identify and cultivate crops, and to develop supporting technologies, which facilitate commercial viability under a wide variety of conditions and locations.

This project supplies producers with a blueprint for greenhouse fabrication that will withstand snow accumulation in mountain/high altitude conditions, encourage and maintain plant growth/crop productivity and maximize light exposure and minimize input costs such as artificial lighting and heating. In addition to greenhouse fabrication, 11 different varieties of hardy, cold tolerant commercial leafy vegetable were trialed to identify potential commercially viable winter salad greens that may be grown under low temperature/low light conditions.

Methods and Materials

Greenhouse construction: Two high tunnel structure greenhouses were constructed at Terra Firma farms in Revelstoke B.C. obtained from Paul Boers manufacturing[2]. One greenhouse (GH1) was 50' by 21' with a single layer of poly and 4' purlins that can withstand a snow load of 50 to 55 PSFT (pounds per square foot). By reducing the span of the purlins to two foot centers, the snow load capacity will be 100 to 110 PSFT. The second greenhouse (GH2) had a double layer of poly on 4' centres with 60 to 80 PSFT, reducing the purlins to 2' will give 120 PSFT. It also featured a fan system to create a cushion of air between the two ply roof to act as an insulator and prevent heat loss.

[1] http://climatemodels.forestry.ubc.ca/climatebc/

[2] http://www.paulboers.com/wp/products/freestanding-greenhouse/

Figure 1: High-tunnel greenhouse structures constructed in Revelstoke B.C. Greenhouse on left is single layered and uninsulated (GH1) while greenhouse on right is double layered and insulated with air (GH2).

Environmental monitoring: An automated HOBO RX3000 data system[3] was used to monitor and compare environmental conditions in both greenhouses simultaneously using remote sensors for photosynthetically active radiation (PAR), air temperature, relative humidity, soil temperature, and soil moisture. Data was stored locally and burst transmitted via internet link to HOBO servers and broadcast to publicly accessible project website[4] in real time.

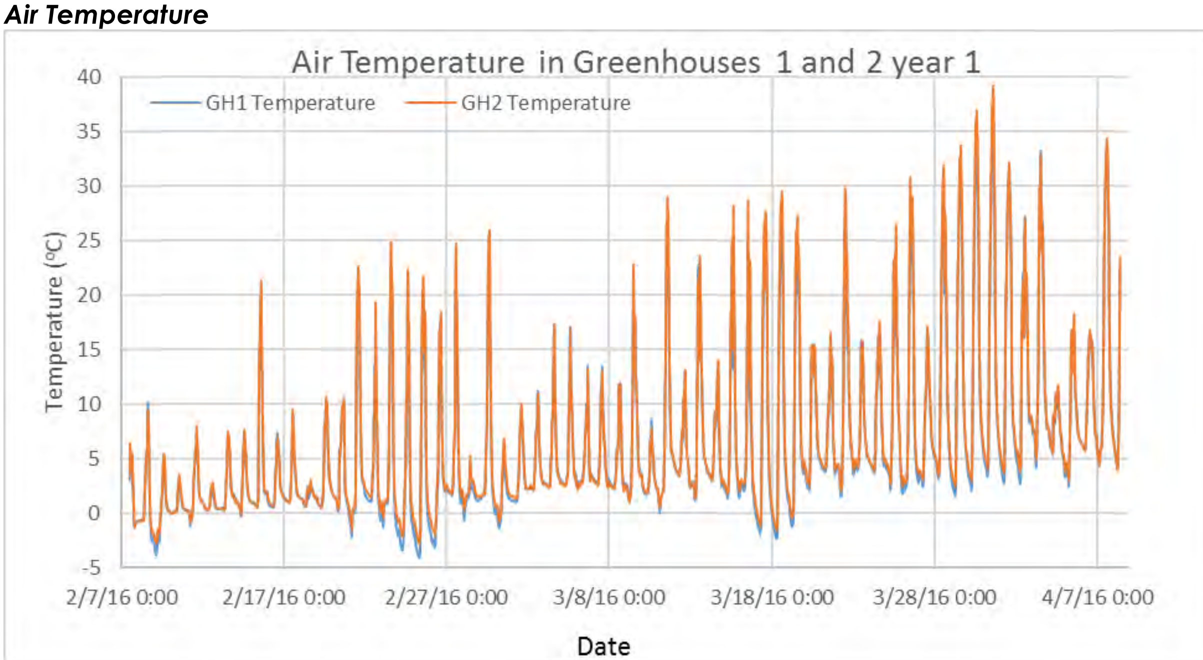
Variety selection and planting: Commercial seeds readily available for greenhouse production were used. Eight varieties were tested in year one of this project and three more varieties were tested in year two: Red kitten spinach, Salanova lettuce, Winter density lettuce, Refugio lettuce, Rouge d'hiver lettuce, Pearl lettuce, Rainbow Kale, Vates Kale, Curly Roja Kale, Flamingo Chard, and Red Devil beet. The seeds were initially germinated at room temperature with artificial lighting for four to five weeks. Seedlings were then gradually hardened off to acclimatize to the cooler temperatures for five days and then were transferred to cedar boxes in the greenhouses. Plant varieties were organized using a random split plot design with multiple samples to limit effects from location bias within the greenhouses.

[3] http://www.onsetcomp.com
[4] http://www.lowlightgreenhouses.com/index.html

Plant assessment: Plant viability and production were determined by randomly selecting five to six plants of each tested variety from each plot. The plant leaves were digitally photographed and images were scanned using the EasyLeafAreaV2 software with leaf scanner settings appropriate to each variety (default setting for the program) and its relative green to red ratio peculiarities. Surface area (cm^2) values from this program were obtained and recorded. The wet leaf weights were determined and the leaves were then dried in a vacuum oven for one to two weeks to remove water and dry weights determined and recorded. Marketability was determined by visual assessment of plant varieties and recording wet marketable weight upon harvest and eventual sale.

Results

Air Temperature



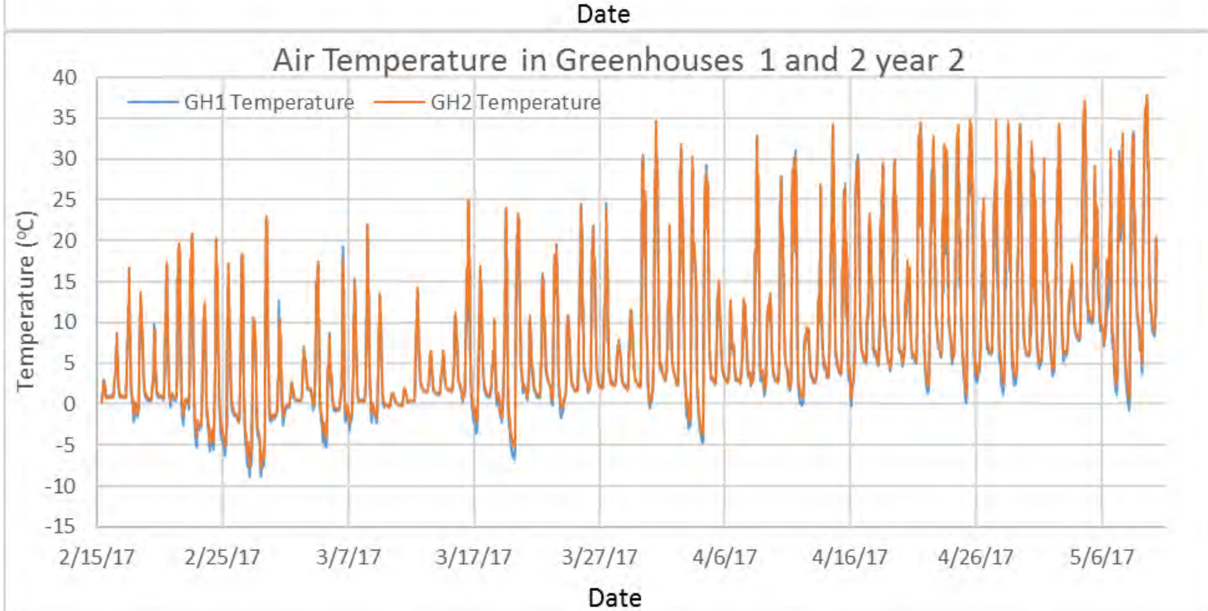


Figure 2: Comparison of air temperature from year one and two of this study in single layered un-insulated greenhouse (GH1) and double layered insulated greenhouse (GH2).

Air temperature measurements were taken roughly 2 m above ground in each greenhouse by the HOBO automated data system (see Figure 2). Temperatures within the greenhouse fluctuated based on a diurnal cycle and general seasonal warming trends. Even in winter, temperatures can exceed 20°C during the day while nighttime temperatures are often close to freezing and, occasionally, below freezing. Overall the insulated greenhouse (GH2) was found to be warmer during both day and night time. On average the insulated greenhouse was 0.43 ± 0.15°C warmer in year one and 0.50 ± 0.09°C warmer in year two.

Night-Time Minimum Temperature

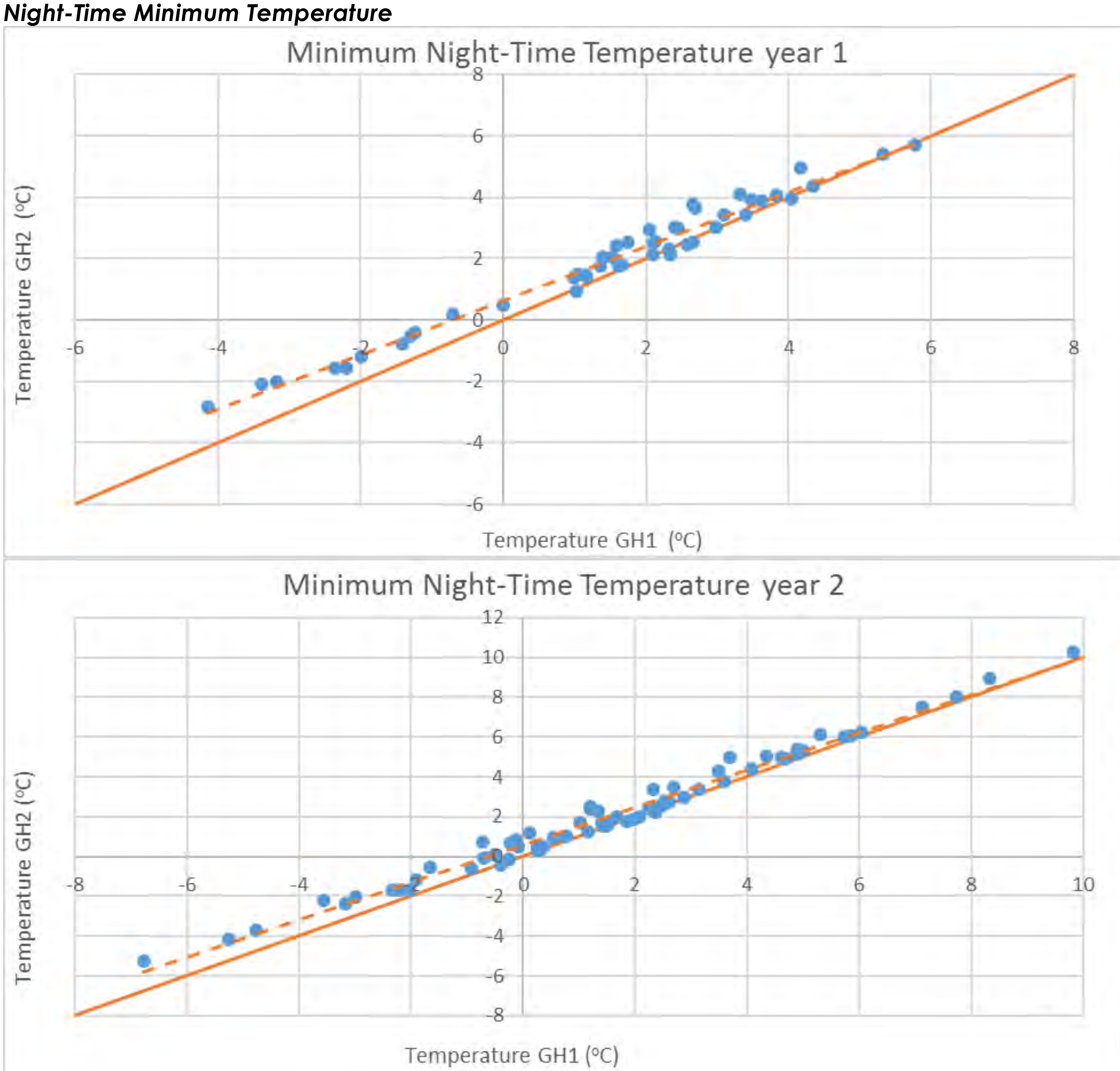
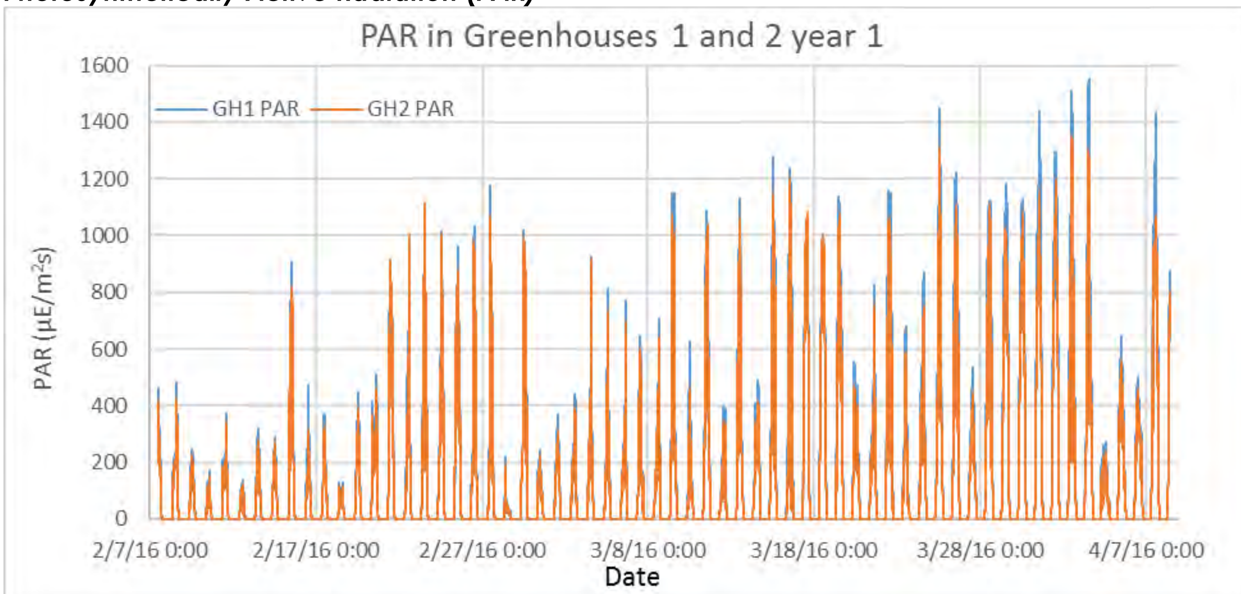


Figure 3: Comparison of nighttime air temperatures from year one and two of this study in single layered uninsulated greenhouse (GH1) and double layered insulated greenhouse (GH2).

The night-time minimum daily temperature was calculated for each greenhouse (see Figure 3). The insulated greenhouse (GH2) was found to be warmer than the un-insulated greenhouse (GH1) with an average minimum night-time temperature difference of 0.39 ± 0.10°C in year one and 0.52 ± 0.10°C in year two. The insulated greenhouse (GH2) had 14 sub-zero nights compared to 15 sub-zero nights in the un-insulated greenhouse in year one. In year two the insulated greenhouse experienced 23 sub-zero nights compared to the un-insulated greenhouse that had 29 sub-zero nights. This is significant as the average air temperature difference is more pronounced for sub-zero nights (0.71 ± 0.24°C and 0.84 ± 0.16°C for years one and two respectively).

Photosynthetically Active Radiation (PAR)



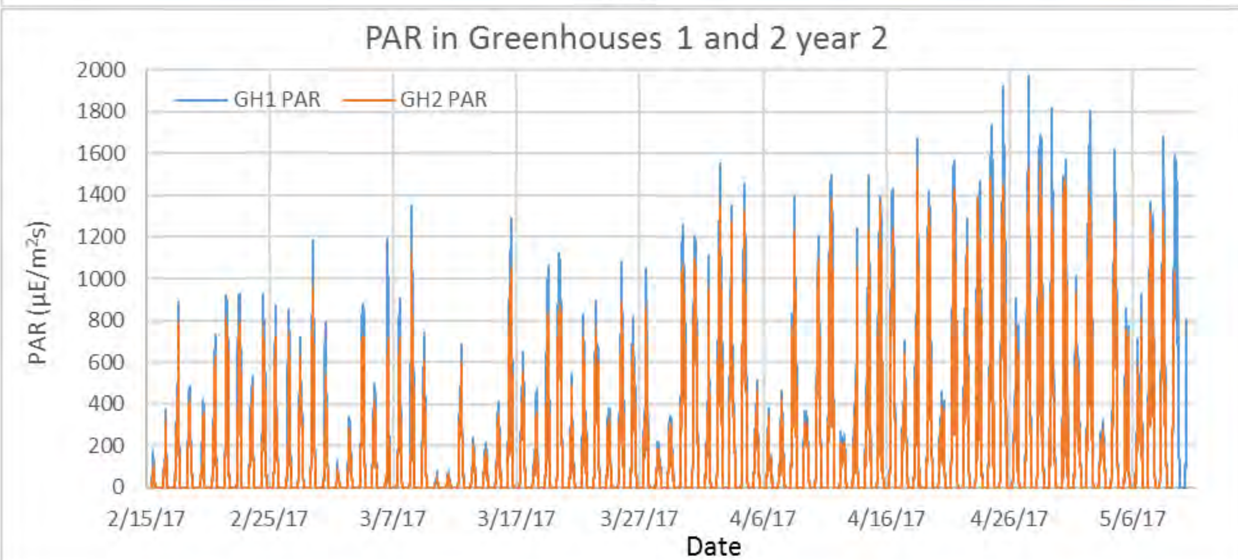
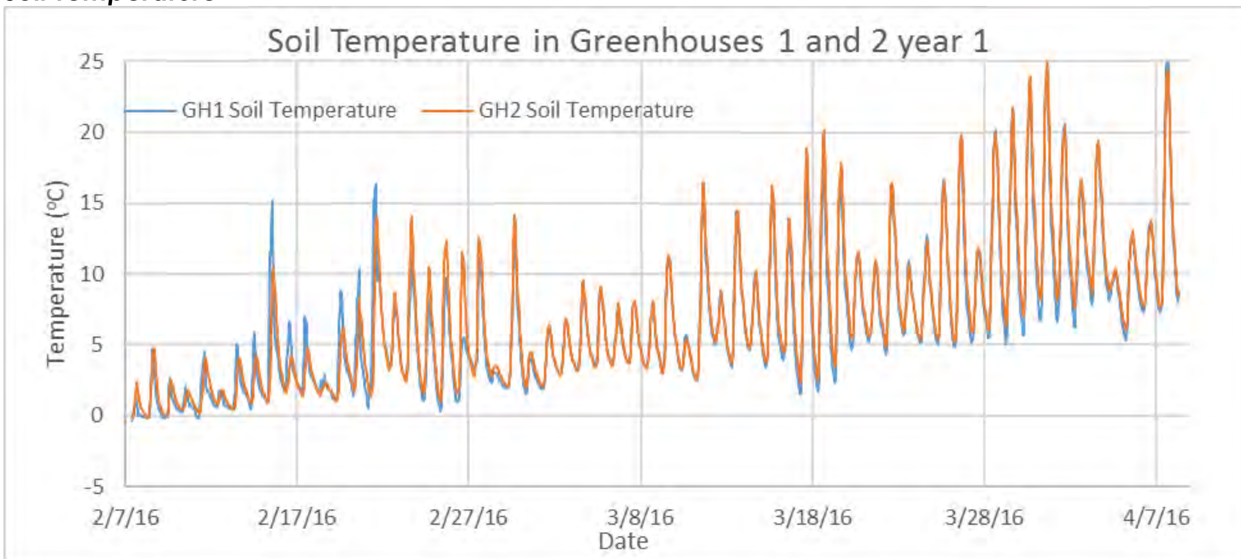


Figure 4: Comparison of photosynthetically active radiation (PAR) from year one and two of this study in single layered un-insulated greenhouse (GH1) and double layered insulated greenhouse (GH2).

Light intensity was measured at roughly 2 m above ground in each greenhouse by the HOBO automated data system (see Figure 4). PAR intensity within the greenhouses fluctuated based on a diurnal cycle and general seasonal trends. Overall the un-insulated greenhouse (GH1) allowed more PAR transmission with 15 ± 2 μE/m²s in year one and 23 ± 3 μE/m²s in year two compared to the insulated greenhouse (GH2)

Soil Temperature



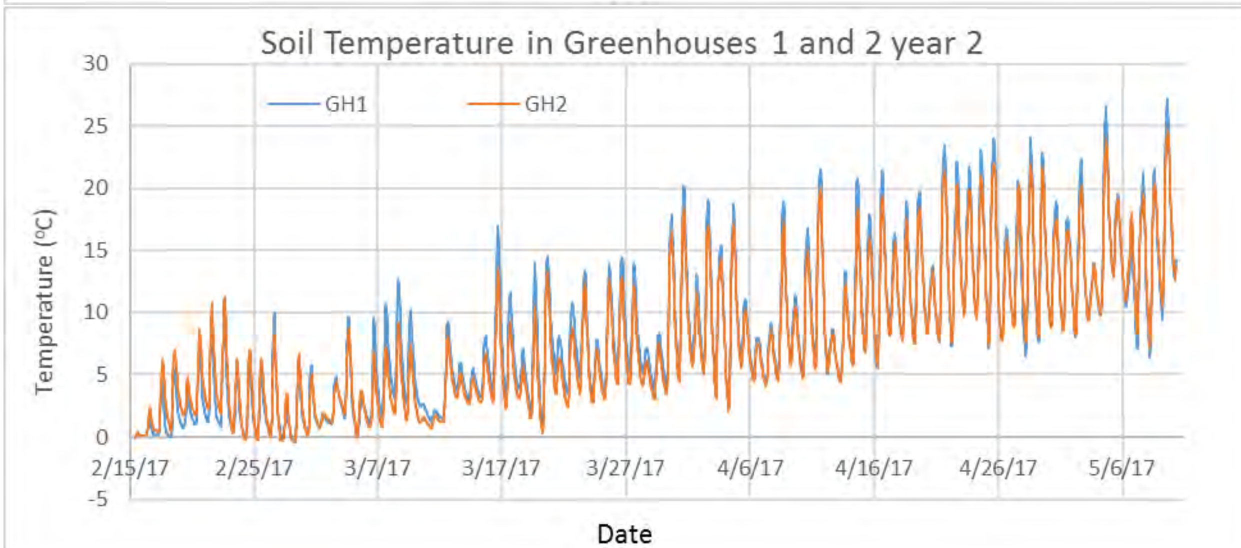
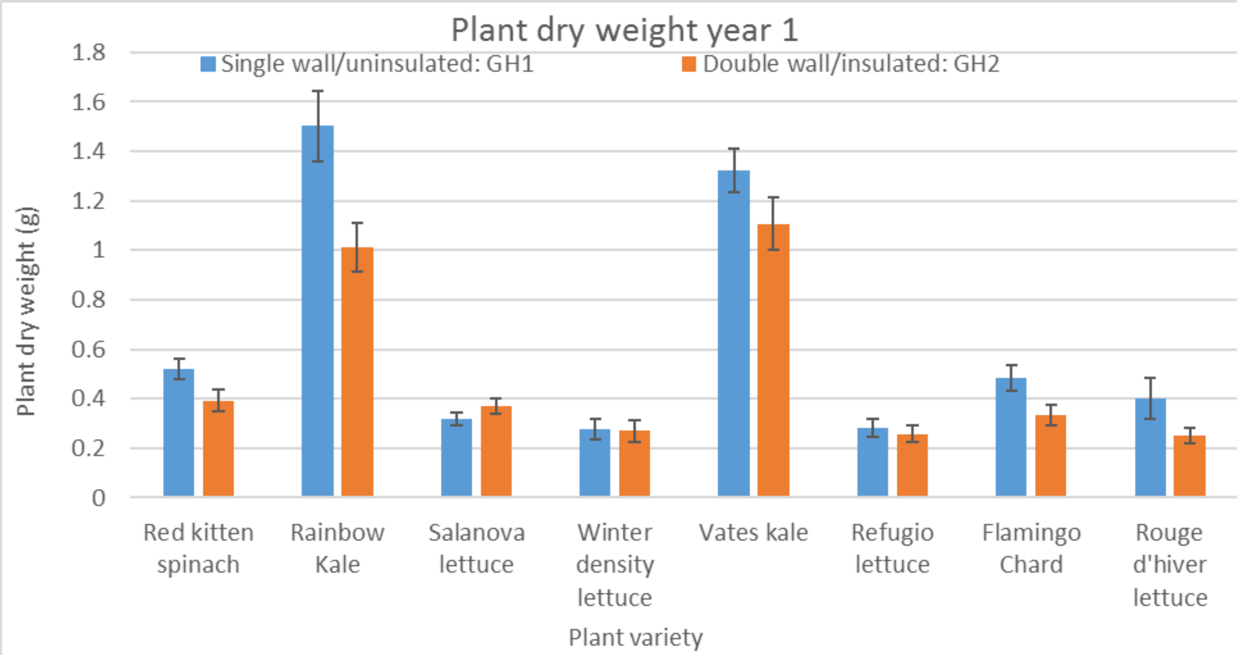


Figure 5: Comparison of soil temperature from year one and two of this study in single layered un-insulated greenhouse (GH1) and double layered insulated greenhouse (GH2).

Soil temperature was measured in a number of beds and averaged for each greenhouse (see Figure 5). As expected the soil temperature mirrored the air temperature but was slightly warmer and held the heat for longer with noticeable slopes at night indicative of slow heat release. For the most part soil temperatures remained above freezing even in early February for both greenhouses.

Plant Dry Weights



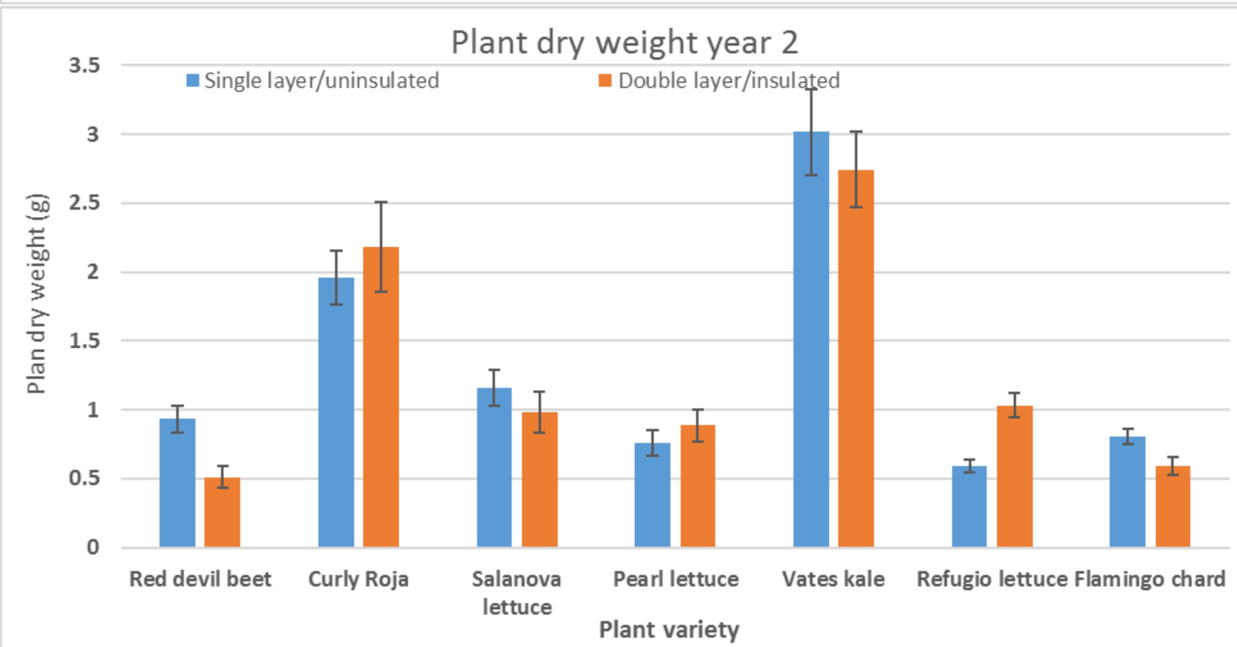


Figure 6: Comparison of plant dry weight from year one and two of this study in single layered un-insulated greenhouse (GH1) and double layered insulated greenhouse (GH2).

Representative plant samples were collected from all replicate plots in each greenhouse and dry weights were determined for each variety tested (see Figure 6). In year one the un-insulated greenhouse (GH1) had higher average dry weights for five varieties (Red Kitten spinach, Rainbow Kale, Vates Kale, Flamingo Chard, Rouge d'hiver lettuce) while the insulated greenhouse (GH2) had higher dry weight for Salanova lettuce (see Figure 6). In year two the un-insulated greenhouse (GH1) had higher average dry weights for five varieties (Red Devil lettuce, Vates Kale, and Salanova lettuce) while the insulated greenhouse (GH2) had higher dry weight for Curly Roja, Pearl lettuce, and Refugio lettuce (see Figure 6).

Plant Leaf Area

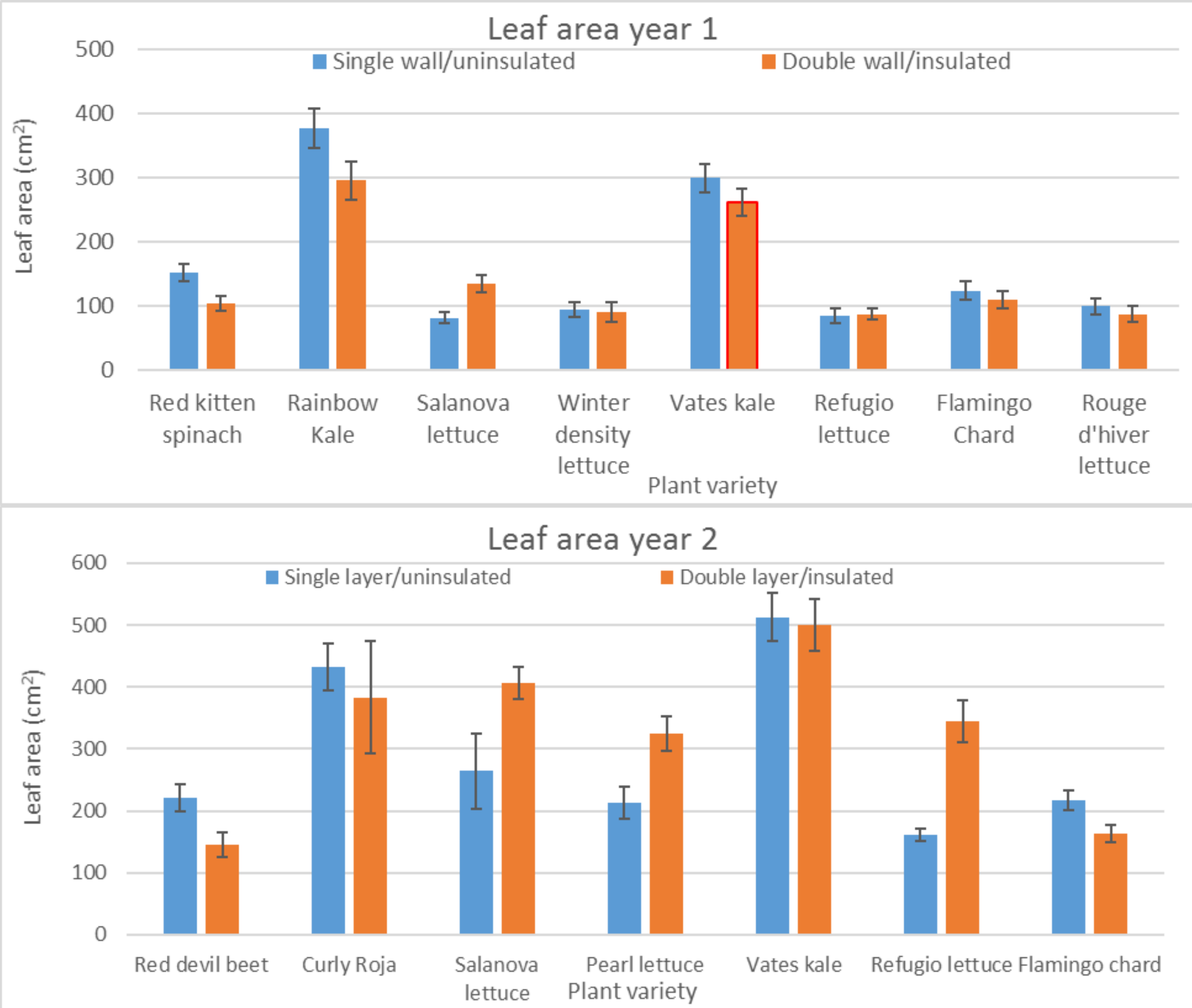


Figure 7: Comparison of plant leaf areas from year one and two of this study in single layered un-insulated greenhouse (GH1) and double layered insulated greenhouse (GH2).

Representative plant samples were collected from all replicate plots in each greenhouse and leaf surface area determined for each variety tested (see Figure 7). In year one the un-insulated greenhouse (GH1) had higher average leaf surface areas for five varieties (Red Kitten spinach, Rainbow Kale, Vates Kale, Flamingo Chard, Rouge d'hiver lettuce) while the insulated greenhouse (GH2) had higher average leaf surface area for Salanova lettuce (see Figure 7). Winter density and Refugio lettuce showed no significant difference between the two greenhouses. In year two the un-insulated greenhouse (GH1) had higher average leaf surface area for three varieties (Red Devil beet, Curly Roja, Vates Kale, and Flamingo Chard) while the insulated greenhouse (GH2) had higher average leaf surface area for three varieties (Salanova lettuce, Pearl lettuce, and Refugio lettuce; see Figure 7).

Marketable Yield

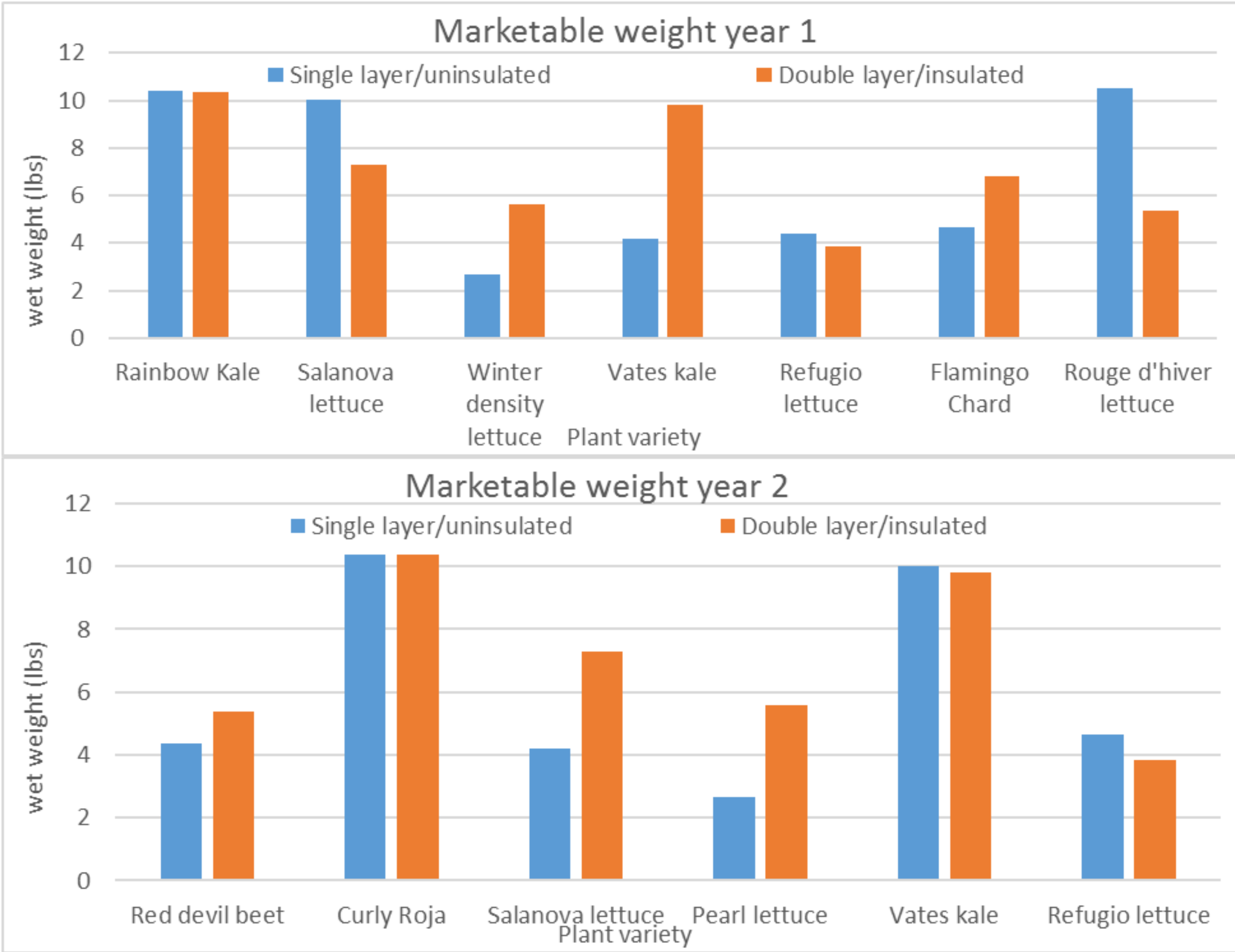


Figure 8: Comparison of plant marketable weights from year one and two of this study in single layered un-insulated greenhouse (GH1) and double layered insulated greenhouse (GH2).

Survival of plantings in February were high with maturity about 60 days after transplanting from 3 to 4 week old seedlings. In year 1 the un-insulated greenhouse (GH1) had higher marketable wet weights for two varieties (Salanova and Rouge d'hiver lettuce) while the insulated greenhouse (GH2) had higher marketable wet weights for three varieties (winter density lettuce, Vates Kale, Flamingo Chard; see Figure 8). In year 2 only Refugio lettuce showed higher marketable wet weight in the un-insulated greenhouse (GH1) while the insulated greenhouse (GH2) had higher marketable wet weight for three varieties (Red devil beet, Salanova lettuce, and Pearl lettuce; see Figure 8). There was 5% and 40% higher yield in the insulated greenhouse (GH2) for years one and two respectively.

Conclusions

This project has demonstrated that high tunnel greenhouse structures can withstand high snow load in alpine conditions like Revelstoke. It has also demonstrated plant viability from February to April in two consecutive years despite low temperatures and low light conditions of the region. Attempts at October plantings in both years of this project resulted in 100% crop loss despite attempts at protecting the seedlings and beds with Remay fabric. In the current research year October plantings suffered 50% crop loss in the un-insulated greenhouse and 25%

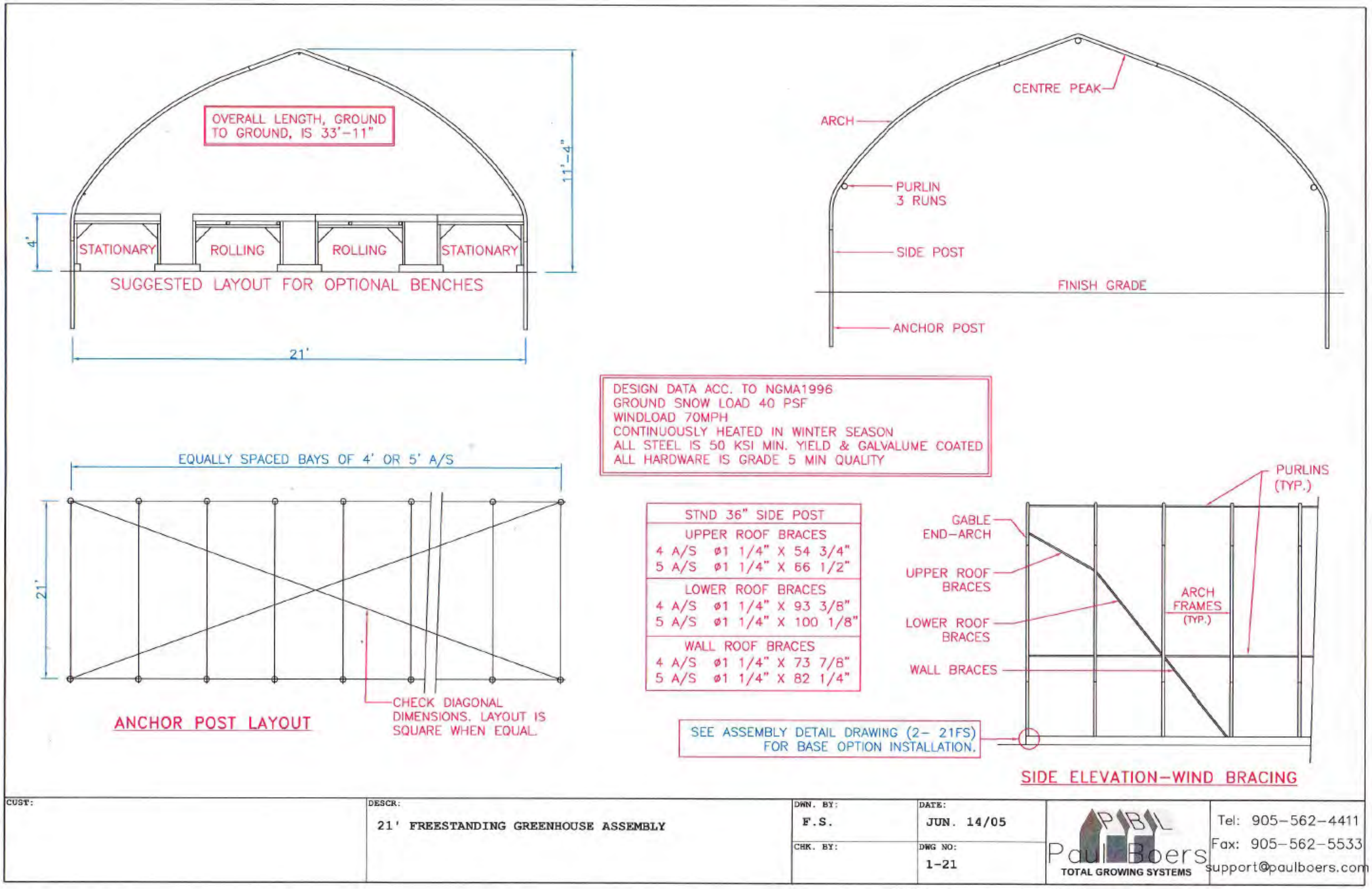
loss in the insulated greenhouse likely due to the use of a Dewitt Ultimate overwinter cover (data not shown).

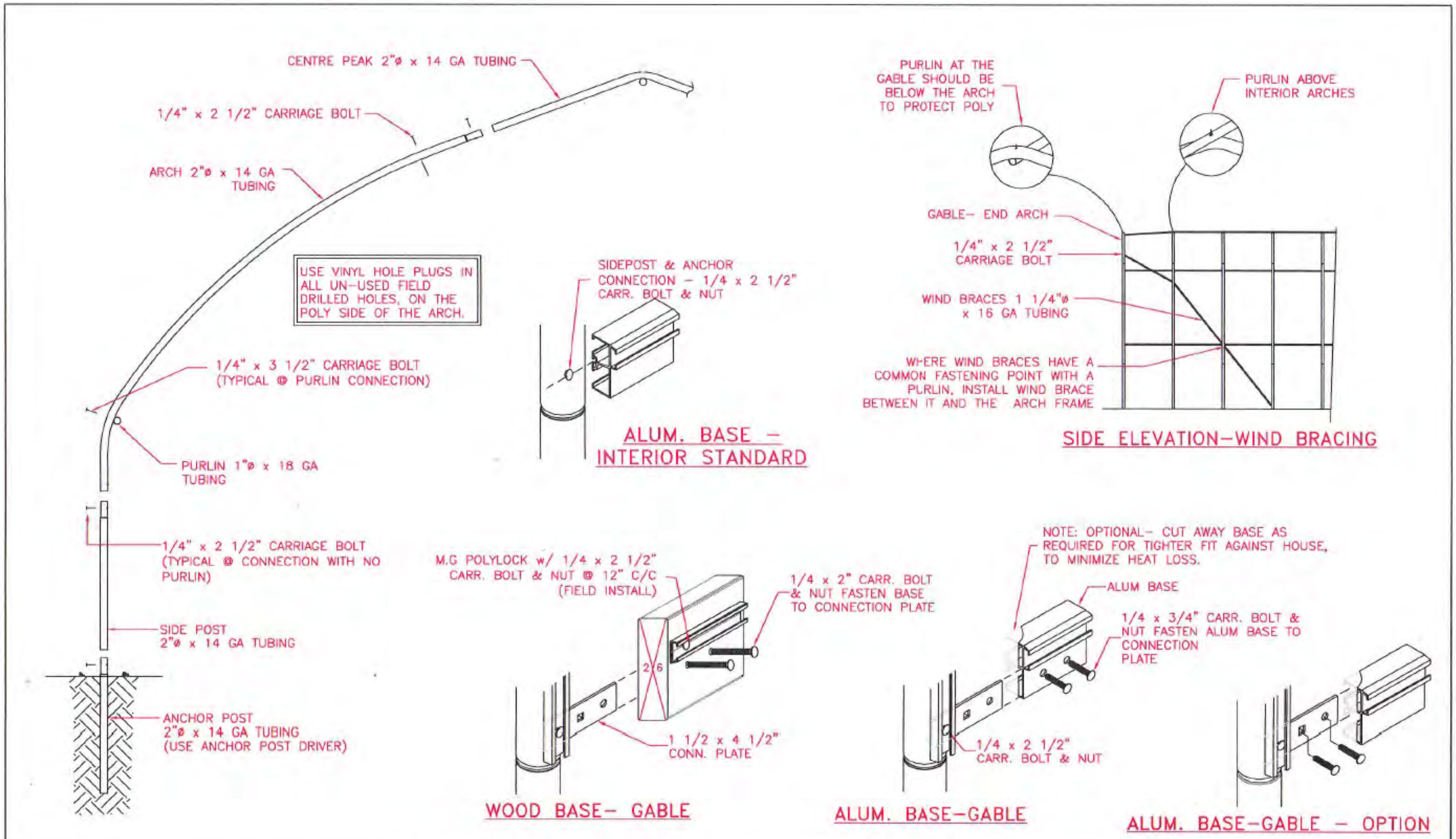
Environmental analysis has shown the un-insulated single layer greenhouse was, on average, colder than the double layer insulated greenhouse in terms of air and soil temperatures. In contrast, photosynthetically available radiation (PAR) was higher in the single layer un-insulated greenhouse than in the double layer insulated greenhouse. These trends were conserved in both years' analyses suggesting consistent performance in the structures from year to year. Surprisingly without any external heat source and relying solely on passive solar radiation daytime temperatures in both greenhouses reached temperatures as high as 20°C even in the low external temperatures in the winter months. One issue that is worthy of consideration is risk of freezing. At below-freezing temperatures, the insulated greenhouse is significantly warmer than the un-insulated greenhouse (by 1 to 2 degrees). This may constitute an advantage for the insulated greenhouse if it reduces the risk of catastrophic crop loss due to freezing of the soil.

Plant growth responses to the greenhouses were variable. Interestingly the large leafed stalked varieties such as the Kales, Red devil beet, and Red kitten spinach performed better in the un-insulated colder greenhouse. We suspect this has to do with the higher PAR availability in the single walled u-ninsulated greenhouse. It would seem these varieties may be more sensitive/responsive to light levels than cold temperatures. In contrast the majority of lettuce varieties trialed performed better in the warmer insulated greenhouse and this may reflect their flexibility when it comes to light exposure or preference for higher temperatures. These observations may be helpful to producers in terms of their selection of high tunnel greenhouse structures since temperature alone is not the driving force for plant success. It may be a case of matching or balancing the appropriate plant variety with the greenhouse that will match their temperature and light requirements. From a producer perspective Salanova lettuce, Rainbow Kale, Vates kale, Red devil beet, and Flamingo chard were the most successful varieties tested.

Appendix A

Greenhouse Structure Assembly

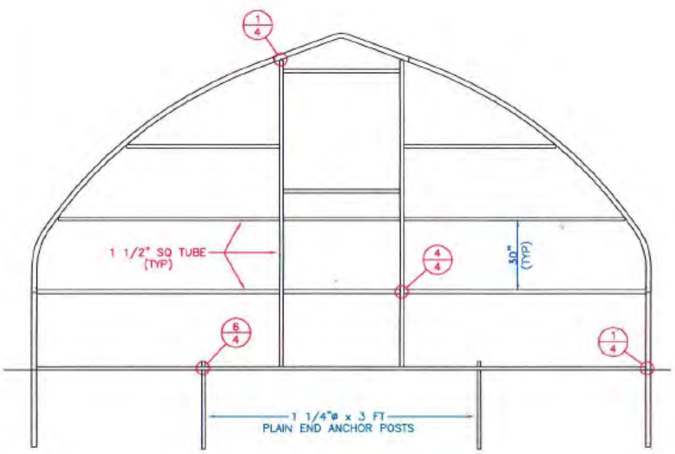

OVERALL LENGTH, GROUND TO GROUND, IS 33'-11"
11'-4"
4'
STATIONARY
ROLLING
ROLLING
STATIONARY
SUGGESTED LAYOUT FOR OPTIONAL BENCHES
21'
CENTRE PEAK
ARCH
PURLIN 3 RUNS
SIDE POST
FINISH GRADE
ANCHOR POST
DESIGN DATA ACC. TO NGMA1996
GROUND SNOW LOAD 40 PSF
WINDLOAD 70MPH
CONTINUOUSLY HEATED IN WINTER SEASON
ALL STEEL IS 50 KSI MIN. YIELD & GALVALUME COATED
ALL HARDWARE IS GRADE 5 MIN QUALITY
EQUALLY SPACED BAYS OF 4' OR 5' A/S
21'
ANCHOR POST LAYOUT
CHECK DIAGONAL DIMENSIONS. LAYOUT IS SQUARE WHEN EQUAL.
STND 36" SIDE POST
UPPER ROOF BRACES
4 A/S ø1 1/4" X 54 3/4"
5 A/S ø1 1/4" X 66 1/2"
LOWER ROOF BRACES
4 A/S ø1 1/4" X 93 3/8"
5 A/S ø1 1/4" X 100 1/8"
WALL ROOF BRACES
4 A/S ø1 1/4" X 73 7/8"
5 A/S ø1 1/4" X 82 1/4"
GABLE END-ARCH
UPPER ROOF BRACES
LOWER ROOF BRACES
WALL BRACES
PURLINS (TYP.)
ARCH FRAMES (TYP.)
SEE ASSEMBLY DETAIL DRAWING (2- 21FS) FOR BASE OPTION INSTALLATION.
SIDE ELEVATION-WIND BRACING
CUST:
DESCR:
21' FREESTANDING GREENHOUSE ASSEMBLY
DWN. BY:
F.S.
CHK. BY:
DATE:
JUN. 14/05
DWG NO:
1-21
Paul Boers
TOTAL GROWING SYSTEMS
Tel: 905-562-4411
Fax: 905-562-5533
support@paulboers.com

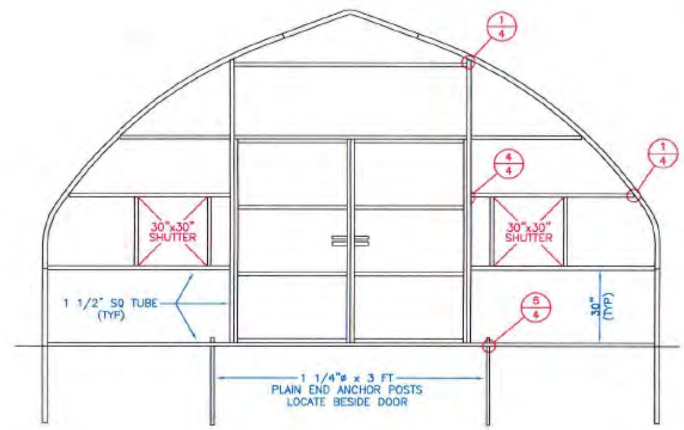


CUST:	DESCR: 21' FREESTANDING GREENHOUSE ASSEMBLY DETAILS	DWN. BY: F.S.	DATE: FEB. 02/09	Paul Boers TOTAL GROWING SYSTEMS	Tel: 905-562-4411
		CHK. BY:	DWG NO: 2-21		Fax: 905-562-5533 support@paulboers.com

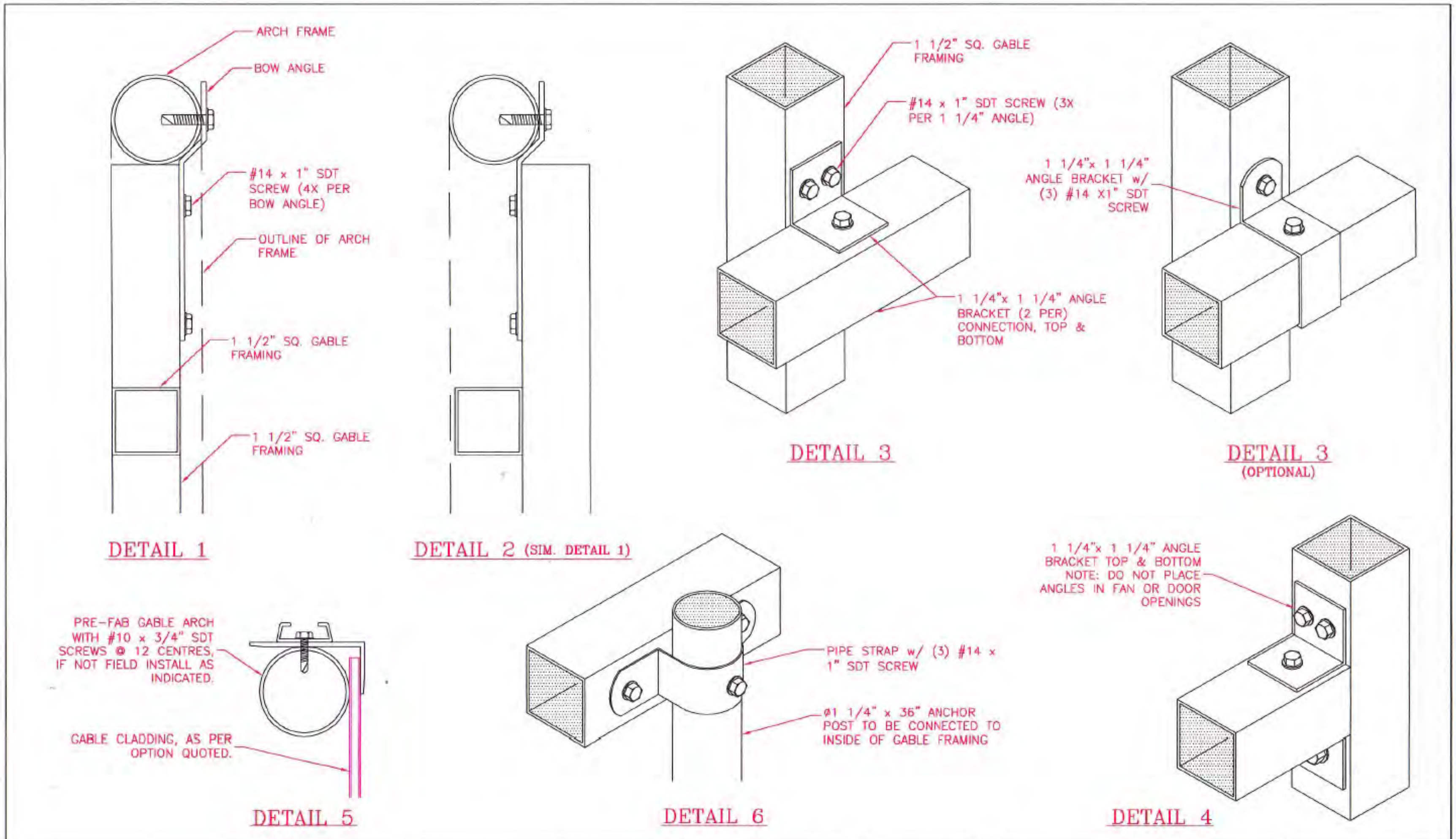
FRAMING NOTES

1. FOR DOOR FRAMING DIMENSIONS, SEE SEPARATE DRAWING.
2. FOR FRAMING DIMENSIONS OF FANS AND SHUTTERS, MEASURE THE ACTUAL UNIT. BE SURE TO ALLOW FOR ANY BOLT HEADS ON THE OUTSIDE OF THE UNIT.

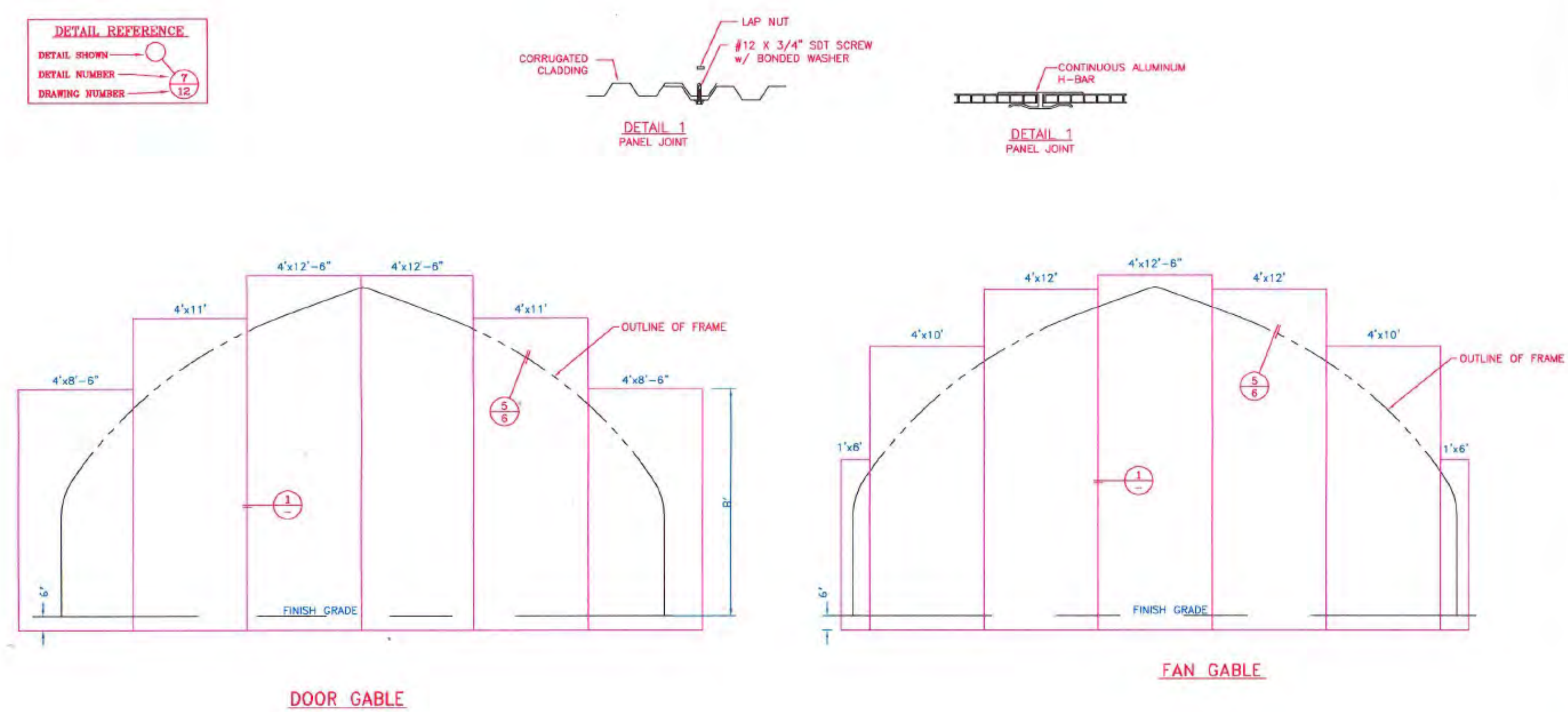




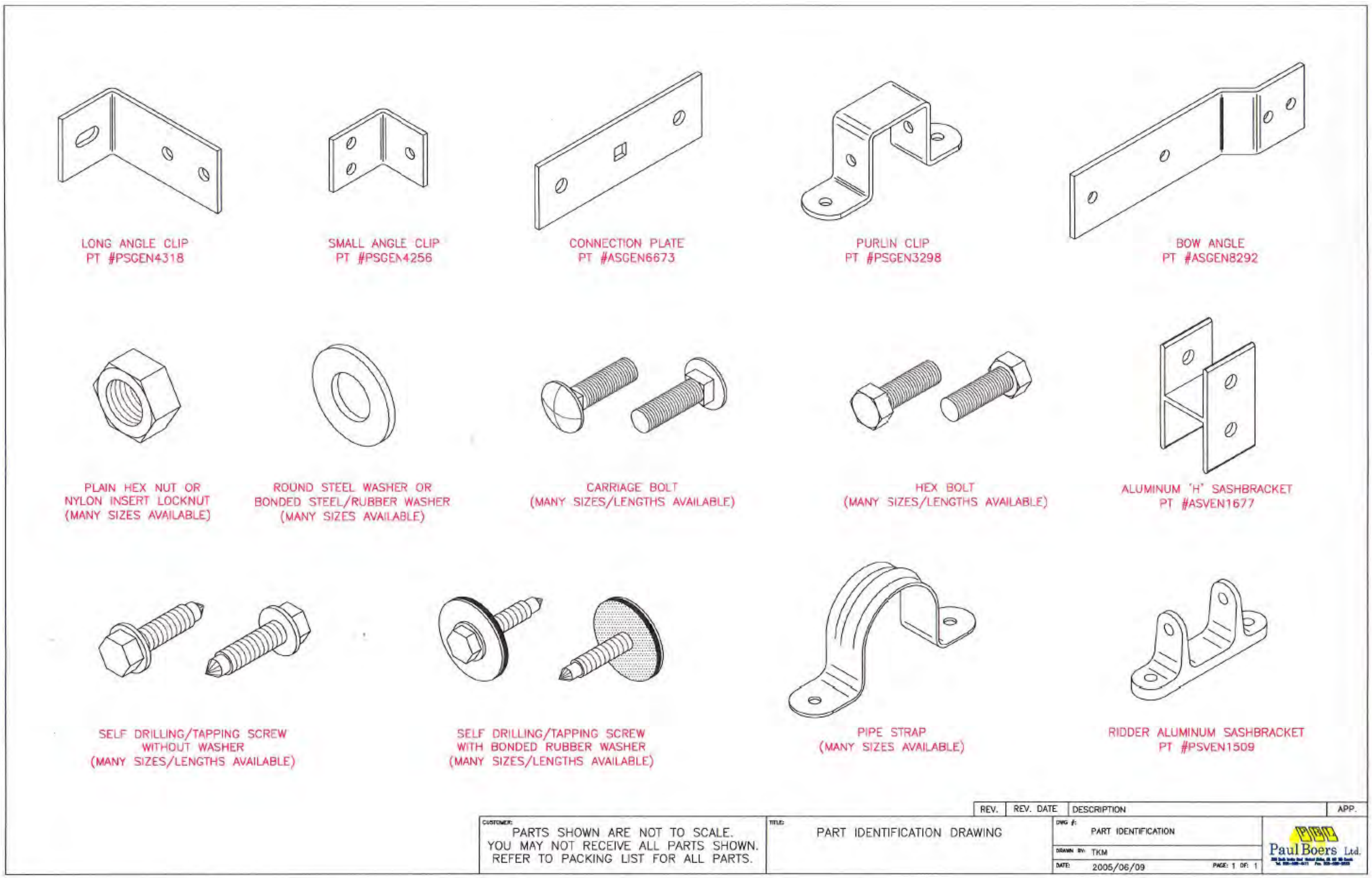
CUST:	DESCR:	DWN. BY:	DATE:		
	21' FREESTANDING GREENHOUSE ASSEMBLY	F.S.	MAY. 04/04	Paul Boers TOTAL GROWING SYSTEMS	Tel: 905-562-4411
	GABLE FRAMING-DOOR SAMPLE	CHK. BY:	DWG NO: 3-21		Fax: 905-562-5533 support@paulboers.com



CUST:	DESCR: FREESTANDING "WIDESPAN" GREENHOUSE GABLE FRAMING DETAILS	DWN. BY: F.S. CHK. BY:	DATE: JUN. 14/05 DWG NO: 4-21GF	Paul Boers TOTAL GROWING SYSTEMS	Tel: 905-562-4411 Fax: 905-562-5533 support@paulboers.com



CUST:	DESCR: 21' FREESTANDING GREENHOUSE ASSEMBLY GABLE CLADDING-DOOR/ FAN SAMPLE	DWN. BY: F.S. CHK. BY:	DATE: MAY. 04/04 DWG NO: 5-21	Paul Boers TOTAL GROWING SYSTEMS	Tel: 905-562-4411 Fax: 905-562-5533 support@paulboers.com


LONG ANGLE CLIP
PT #PSGEN4318
SMALL ANGLE CLIP
PT #PSGEN4256
CONNECTION PLATE
PT #ASGEN6673
PURLIN CLIP
PT #PSGEN3298
BOW ANGLE
PT #ASGEN8292
PLAIN HEX NUT OR
NYLON INSERT LOCKNUT
(MANY SIZES AVAILABLE)
ROUND STEEL WASHER OR
BONDED STEEL/RUBBER WASHER
(MANY SIZES AVAILABLE)
CARRIAGE BOLT
(MANY SIZES/LENGTHS AVAILABLE)
HEX BOLT
(MANY SIZES/LENGTHS AVAILABLE)
ALUMINUM 'H' SASHBRACKET
PT #ASVEN1677
SELF DRILLING/TAPPING SCREW
WITHOUT WASHER
(MANY SIZES/LENGTHS AVAILABLE)
SELF DRILLING/TAPPING SCREW
WITH BONDED RUBBER WASHER
(MANY SIZES/LENGTHS AVAILABLE)
PIPE STRAP
(MANY SIZES AVAILABLE)
RIDDER ALUMINUM SASHBRACKET
PT #PSVEN1509
REV.
REV. DATE
DESCRIPTION
APP.
CUSTOMER:
PARTS SHOWN ARE NOT TO SCALE.
YOU MAY NOT RECEIVE ALL PARTS SHOWN.
REFER TO PACKING LIST FOR ALL PARTS.
TITLE:
PART IDENTIFICATION DRAWING
DWG #: PART IDENTIFICATION
DRAWN BY: TKM
DATE: 2005/06/09
PAGE: 1 OF: 1
Paul Boers Ltd.

BUILDING YOUR NEW PAUL BOERS FREESTANDING HOUSE

Thank you for the recent purchase of your Freestanding structure. The intention with this booklet is to make this a very positive experience for those who have built before, as well as those who have not. As we go through the procedures, you will be able to see some helpful hints added, which have been compiled by feedback from professional builders, as well as customers and builders who have called in their comments.

It is very important that you study your drawings and material lists. Quite often, you may see special instructions on your material list, which may only apply to your structure, depending on the options purchased. Some time spent comparing the material list with the components you received will pay off. In the past, some customers have had to remove or disassemble something they did not do correctly. Of course this is not the most cost-effective way of building! Please keep in mind, we are always a phone call away, and there is no need to guess what to do.

REQUIRED TOOLS

A few things you will need to have ready for site preparation:

- Measuring Tape (preferably 100')
- Sledge Hammer
- Mason String (a good quality string that can be pulled tight without breaking)
- Orange or other bright color paint which could be used to paint the 4 corner anchor posts (this is optional, but may be considered to make it easier to see them from a distance)
- A helper would be an asset when laying out the anchor posts. Especially when the house is longer than 24'.
- Stakes
- Step Ladder
- Pipe Wrench, or Screwdriver – (for turning anchor posts into alignment)
- 7/16" & 1/2" Wrench or Socket & Ratchet – Fits ¼" & 5/16" hex nut. A ratchet & socket combination will allow for faster installation of the bolts, but be careful when tightening the hex nuts with the ratchet. Otherwise, you could break the bolts!

STEP # 1 – PARTS IDENTIFICATION

This step will help to familiarize you with the components you receive with your order. The easiest way to do this is to have your material list(s) and drawing(s) together at the start. Compare the drawings to the material list. This should be enough for you to make a positive identification of the components.

STEP # 2 – SITE PREPARATION

This is perhaps one of the most important steps to follow prior to starting the building of your coldframe. Without proper site preparation, as you proceed with the building, you will discover that things will not go together as easily as they would, had you prepared the site adequately beforehand. (Refer to drawing # 02)

- Level building site to enable surface water to run off. Do not exceed slope of 6" over 100'

- The idea is to not have to fill any low spots, as this reduces the "bearing" capacity of the soil around the post.

STEP # 3 – ANCHOR POST INSTALLATION

- A helper would be an asset when laying out the anchor posts. Especially when the house is longer than 24'.

- Using stakes and a 100' tape, lay out the 4 corner posts using the 3,4,5 squaring method (see drawing #s 02 and 03). The 4 corner stakes you install can represent the actual placement of the posts. An accurate layout of posts will definitely facilitate an easier assembly of your structure. When you are measuring out for the next anchor post, always take your measurements from the end post (i.e. from the end post to 4', 8', 12' or 5', 10', 15' etc.). Otherwise, if your first post is out a little (also known as "drifting"), you will duplicate the mistake to other bays of the structure.

- Use Mason string for sides to keep posts in line. Measure the post spacing down the sides using the 100' tape. Mark the post spacing by pressing the post into the ground.

- An anchor post driver is supplied with each greenhouse. This slips over the top of the anchor post, and prevents the top of the post from becoming deformed. Do not try pounding the posts into the ground with as few drives as possible, as this could damage the post driver prematurely, and result in damage to the swaged part of the anchor. Keep the hole in the anchor 90 degrees to the length of the house. If the post turns in the ground, and the hole goes out of alignment, use a pipe wrench to turn the post to the correct position. Also, a screwdriver could be slipped through the holes in the anchor post to turn it to the proper location.

STEP # 4 – ARCH & FRAME ASSEMBLY

- As in drawing # 03, lay out the sideposts, arches, center peaks, etc. Assemble arches as in the drawing. Also, lay the purlins down the sides of where you are to build the structure. Place the bracing at the gable ends. Assemble all components for a complete arch using fasteners as indicated in your drawing and listing package. Do not tighten bolts at this time. Once you have completed an arch, lay it alongside the anchor posts, which have already been driven into the ground (refer to drawing 03-A) in your drawing booklet.

- When all of the arches have been assembled, you are ready to start placing them onto the anchor posts. For this job, it is recommended that you have another person assist. This way, the entire arch can be placed onto the anchor posts, and at the same time, the proper fastener can be slid through the hole in the arch and anchor connection. Again, it is recommended that the bolts are left loose at this time. This enables you to adjust the frame as required, making installation of purlins and bracing easier (refer to drawing 04).

- Once you have installed at least 4 complete arches onto the anchor posts, you may decide to start to install the purlins at this time. If you do, it is more practical to start with the ridge purlin. It is recommended that you install the ridge purlin on the outside of the frame, whereas the 2 runs of side purlin can be installed on the inside of the structure. The reason for having the ridge purlin on the outside of the frame is to keep the poly from stretching too much between the arches (refer to drawing # 04A).

- Starting with the un-swaged end of the purlin facing the outside of gable end of the house, slip a ¼ X 3 ½" carriage bolt through the hole in the purlin and arch. Put on a hex nut, but do not tighten yet. Put the next bolt through, and when you get to the last hole in the purlin, slip the next purlin into the first one, and bolt through this connection into the arch. Carry on this way until all purlins are installed.

- When installing the wind bracing (refer to drawing # 04B & 04C), start by installing on end onto the arch to anchor post connection of the second arch from the gable. The brace will share the bolt at this connection. Again, do not tighten the hex nut at this time.

- Then take your next brace, and install one end onto the connection where the side purlin meets the square gable arch (see drawing # 04C with exploded detail). For this connection, the brace will share the purlin-to-arch bolt. Pin the brace underneath the purlin, and thread on a hex nut.

- Once you have these connections in place, have an assistant hold the gable arch steady with a level placed against the outside of it. Once you are certain that the gable arch is level, the purlins, which you have already installed, should pull the other arches level as well. Now is the time to bring both loose ends of the braces together, and center the holes in the bracing on the arch. You can mark the hole location with a marker then drill the hole, or drill through the bracing hole (using a 17/64" drill bit) into the arch. This connection will be bolted with a ¼" x 2 ½ " carriage bolt and hex nut. Leave the hex nuts on the structure finger-tight until the frame is complete.

- Once you have assembled the entire structure, it is time to tighten the hex nuts. If you are using a ratchet and socket, be careful not to over tighten the hex nuts, or you could snap the bolt off!

This booklet covers the basic structure only. There are various options, which can be added, and will be accompanied by the appropriate drawings and instructions as they are purchased with your order.

We at Paul Boers hope that your building experience will be a pleasant one, and wish you all the best in your business endeavors!

RELEASED MAY 1, 2001

Appendix B

Research Factsheet

Climate Action Initiative
BC AGRICULTURE & FOOD

Adapting to low light/low temperature conditions using high-tunnel structures in Revelstoke, British Columbia

Research Factsheet

Farm Adaptation Innovator Program

Terra Park[1], Rob Jay[1], Andrew Perkins[2], Brian May[3] and Michael Mitsch[3]

Geographic Applicability This study was conducted in Revelstoke and findings may be applied to other regions in British Columbia with limited light exposure and reduced temperatures.

Commodity Relevance This study was conducted on a variety of salad greens grown under low light/low temperature conditions with different greenhouse insulation conditions. The findings may be extended to other hardy greenhouse crops.

Project Timeline September 2015 - February 2018

[1] Owner, Terra Firma Farms, Revelstoke
[2] Professor, Faculty of Geography, SFU, Burnaby
[3] Professor, Faculty of Science, Okanagan College, Salmon Arm

Background

This demonstration project studied the viability of winter salad green production in a low-cost, high-tunnel greenhouse structure heated with compost in low light conditions without supplemental lighting over a three-year period. Many communities in the Columbia Basin and in other regions of British Columbia face similar challenges with their growing conditions as a consequence of regional climates, and potential influences of climate change, such as increased severity and frequency of winter storms, resulting in more extreme fluctuations in light intensity. Transportation of food into these communities creates a variety of attendant issues, including higher costs of transporting produce, and attendant increases in the use of petroleum fuels (and consequent emission of greenhouse gases). The project trialed seven different varieties to find a mix of cold-hardy greens that will provide a high quality mixed green salad for customers.

Study Objectives

- Determine if high-tunnel greenhouses can withstand snow load and temperature variations.
- Identify salad green varieties that may be commercially viable under low light/low temperature conditions with low-cost input.
- Compare single and double layered high-tunnel greenhouse structures for insulation/heat retention abilities and effects on plant yields.

Key Findings

- Double layered, insulated high-tunnel greenhouse is: 1-2^{o}C warmer, soil temperature is 0.72^{o}C higher, reduces PAR by 15.5 $\mu E/m^2s$ and relative humidity by 2.1% compared to a single layer, uninsulated high-tunnel greenhouse.
- Plant viability was demonstrated from February–April with certain varieties preferring the warmer double layered, insulated greenhouse (Salanova and Pearl lettuce), others preferred higher PAR of single walled uninsulated greenhouse (Red kitten spinach, Red devil lettuce, Rainbow kale, Flamingo chard, Rouge d'hiver lettuce), while some varieties (Vates Kale, Refugio and Winter density lettuce) showed no preference.
- First year approximately 100lbs wet yield, 5% more in double layer high tunnel structure.
- Second year approximately 125lbs wet yield, 40% more in double layer high tunnel structure.
- Not all greens handled the stress of cold, low light conditions the same. Salanova Lettuces, Vates Kale and Flamingo Chard have been clear winners.

Definitions

PAR: photosynthetically active radiation; light from visible spectrum absorbed by plants

High tunnel structures: large peaked greenhouses needed for snow shedding/ removal and sunlight accession.

Design

This project was conducted on one site located in Revelstoke. One high tunnel structure had double layer plastic with air insulation while the other had only a single layer covering. Environmental conditions (air and soil temperature, relative humidity, photosynthetically active radiation (PAR), and soil moisture) were collected via automated HOBO data link. Seedlings were planted in February and representative plants collected from replicate plots in April for dry weight and leaf area analysis (2016 and 2017) and commercial wet weights recorded.

Limitations

This study was conducted on an operational farm using a low-cost/input system subject to environmental and seasonal variation in temperature and light exposure resulting in variability between production years. Results indicate all year production is not possible as productivity is very low due to poor environmental conditions.

The current processes can extend the season an extra month but the extra effort clearing snow may not be worth it. Winter is a great time for farmers to rest and rejuvenate!

Next steps

While the findings from this study provide useful information to producers, future work is required to apply these findings to the industry. Environmentally controlled experiments in the greenhouse would provide more information on specific thresholds which farmers can use as guidelines for management practices. The practice is low-cost and low-tech, making it a good fit for communities with limited skills in greenhouse production. Having product ready for the early spring markets is valuable for customer retention but more energy intensive efforts are required for year round production in cold climates with limited sunlight.

Climate Adaptation Implications

Adoption of this technology and agricultural practice may accelerate/extend growth season of salad green production in low temperature/low light regions.

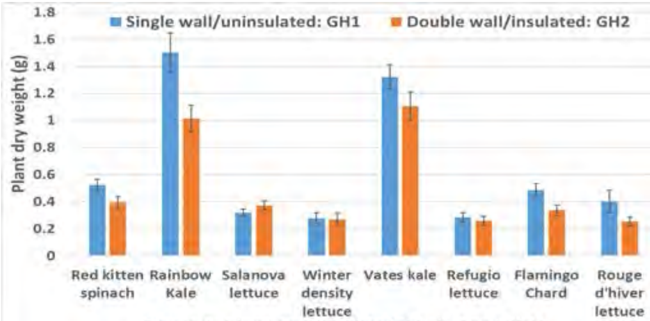


Figure 1: Plant dry weights (g) Feb-April 2016

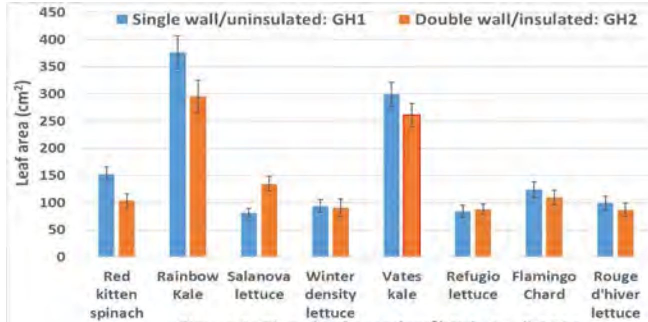


Figure 2: Plant leaf area (cm^2) Feb-April 2016

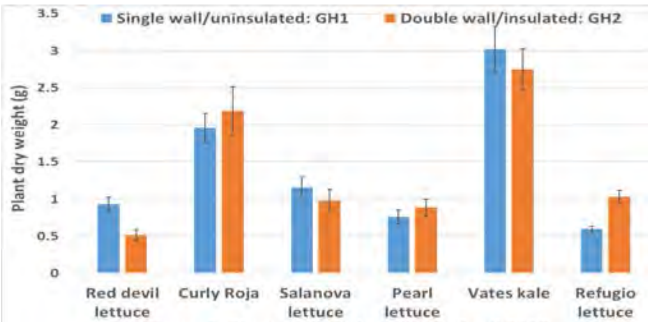


Figure 3: Plant dry weights (g) Feb-April 2017

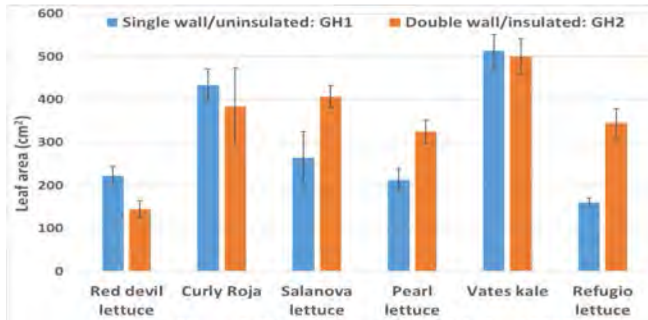


Figure 4: Plant leaf area (cm^2) Feb-April 2017

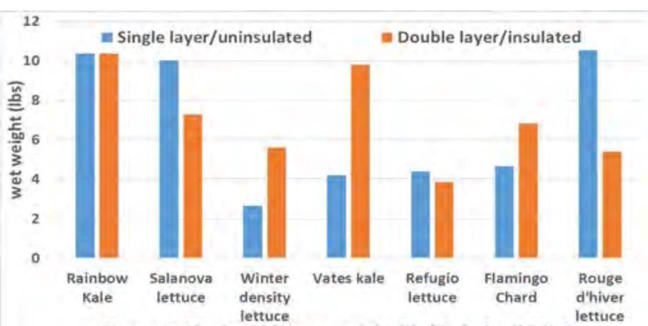


Figure 5: Marketable wet weight (lbs) Feb-April 2016

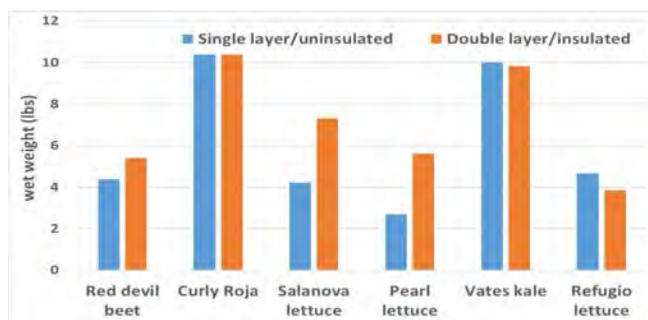


Figure 6: Marketable wet weight (lbs) Feb-April 2017

Figures 1-6: Comparison of plant growth between single layered uninsulated and double layered insulated high-tunnel greenhouse structures.

For more information related to this project and greenhouse production in general:

For more details on this project visit the Climate Action Initiative website:
https://www.bcagclimateaction.ca/faip-project/fi14/

High tunnel greenhouse environmental data from this research available at:
http://www.lowlightgreenhouses.com/index.html

B.C. greenhouse production
https://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/animals-and-crops/crop-production/greenhouse-vegetables

Commercial greenhouse production stats
https://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex1443

Greenhouse season extension
http://www.acornorganic.org/resources/library/video/season-extension-strategies-without-a-greenhouse-greenberg

Harrow Research and Development Centre
http://www.agr.gc.ca/eng/science-and-innovation/research-centres/ontario/harrow-research-and-development-centre/?id=1180624240102

The future of greenhouse production
https://www.greenhousecanada.com/inputs/crop-culture/a-look-into-the-future-3209

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Growing Forward 2
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ardcorp
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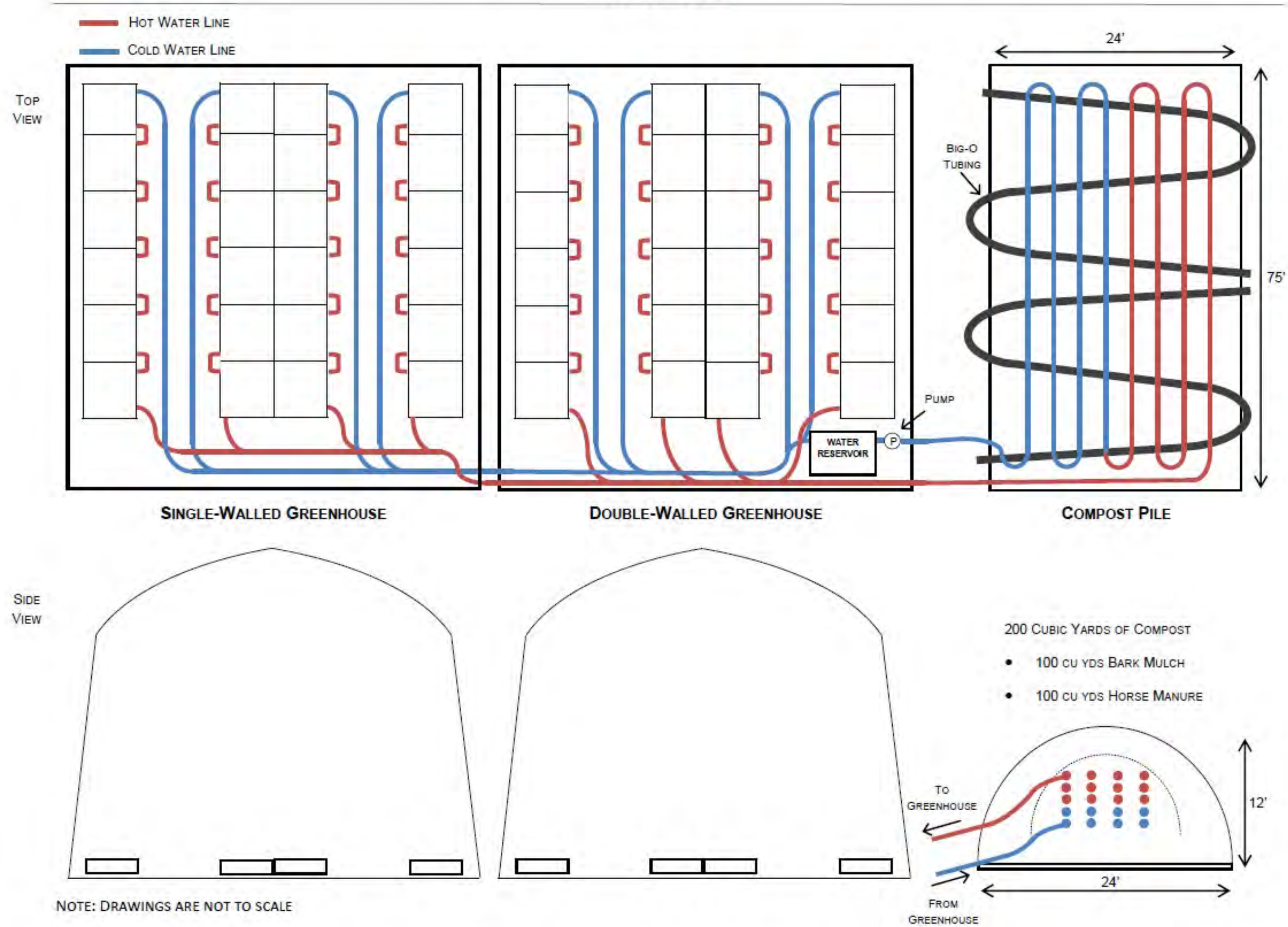
British Columbia
Canada

Appendix C

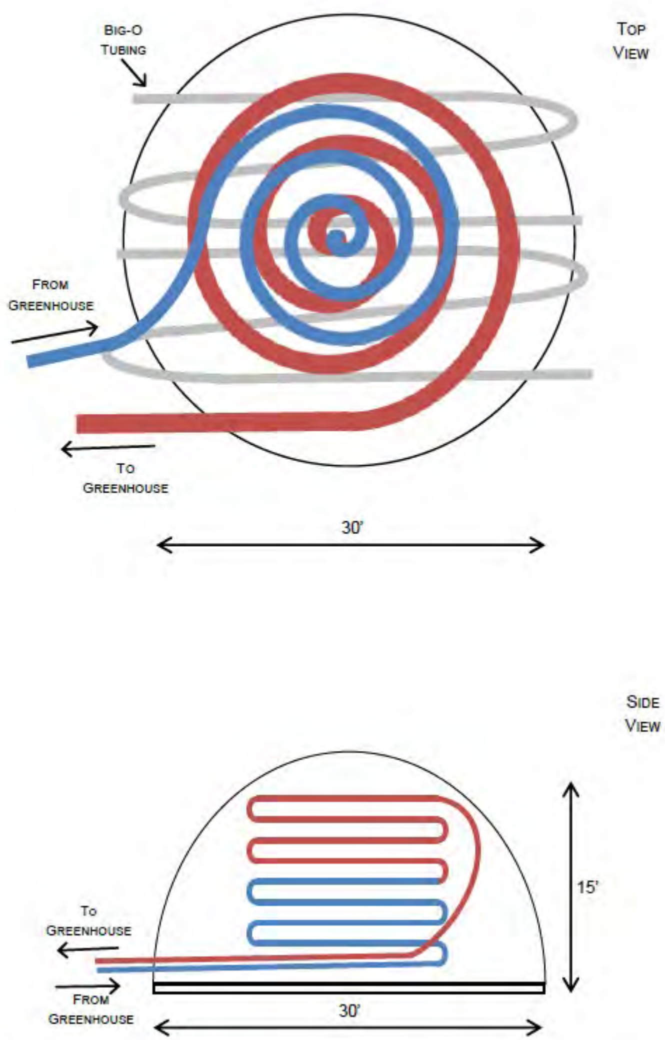
Compost Heat System Information

2017/2018

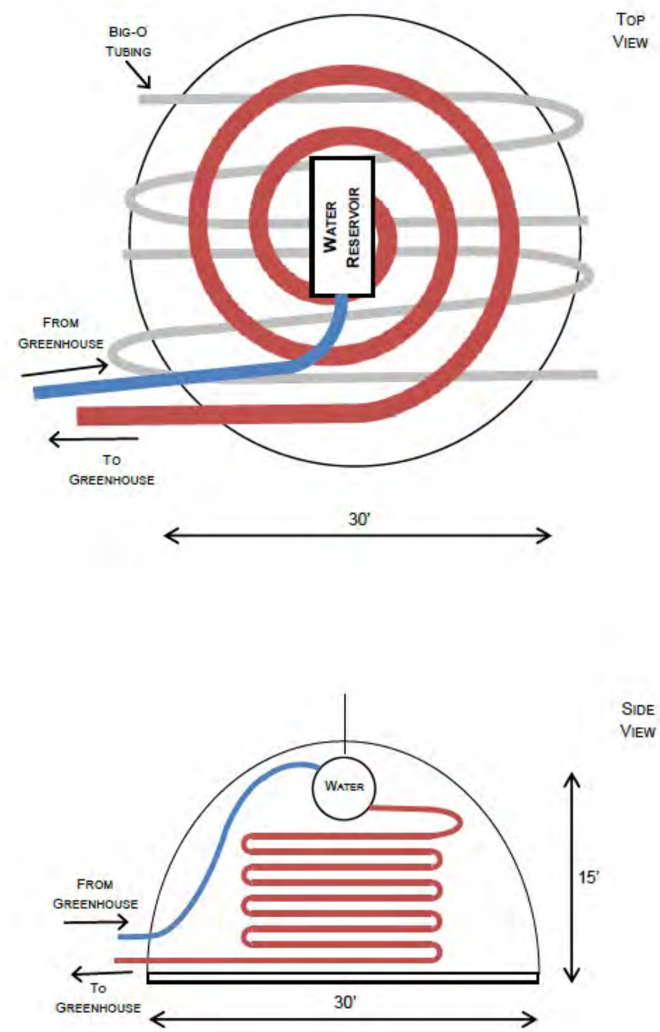


Note: Drawings are not to scale

Compost Pile 2016/2017



Compost Pile 2015/2016



Note: Drawings are not to scale

Materials for Compost Heat System

Compost Pile 2016-2017

- 40 cu yds Bark Mulch
- 75’ of 6’ Perforated Big-O Pipe
- 2000’ of ¾” Poly Tubing

Compost Pile 2017-2018

- 100 cu yds Bark Mulch
- 100 cu yds Horse Manure
- 150’ of 6” Perforated Big-O Pipe
- 5000’ of ¾” Poly Tubing

Heating Manifold

- 45 Gallon Drum
- Grundfos Circulation Pump
- 12 - ¾” NPT - ¾” Barb Connectors
- 6’ of 1” Steel Pipe (attached to drum to refill vertical mounted)
- 100’ of ¾” Poly Tubing (pile to manifolds)
- 20’ of ¾” PVC Pipe
- 12 - ¾” PVC T to ¾” NPT
- 4 - ¾” PVC 90 to ¾” NPT
- 8 - ¾” NPT Valve to ½” Barb (return control)
- 2 - ¾” Ball Valves (pile to manifold)

Beds

- 48 - 20’ rolls of ½” Heavy Poly Tubing
- 400’ of ½” Poly Tubing Return Lines
- 96 - ½” Barbed Elbows

Compost Heat System Construction

Pile needs ample quantities of carbon, nitrogen, oxygen and water. The carbon in the inner layer of the pile will be unavailable at first. The lignins and cellulose in wood chips and sawdust resist decay but that is actually a good quality because the gradual oxidation allows for an extended thermophilic condition that can allow a large compost pile to last up to 18 months.

Compost Construction of Round Design

1. Find level area with good drainage.

2. Put down two 75' lengths of Big-O piping on the ground. Make it so the ends are exposed.

3. Add compost 30' diameter 3' thick.

4. Unravel 3/4" poly tubing. Leave one end sticking out the pile 20'. Label intake.

5. Start laying down the tubing in large coils working into the inside.

6. Add two more feet of compost completely burying layer out coil.

7. Repeat steps five and six until you have about 20' of tubing left so you can run it parallel to the 20' of tubing that is sticking out from the bottom of the pile that you started with.

8. Pressure test the tubing before completely burying the pile.

9. Make sure that there is 4' of material covering all of the tubing without burying the ends of the Big-O tubing.

10. Run the two ends into the greenhouse.

Compost Construction of Linear Design

1. Find a level flat piece with good drainage 30’ wide 80’ long.

2. Put down 150’ of Big-O tubing with the ends exposed.

3. Spread out bark mulch 3’ deep, 20’ x 70‘.

4. Start running lengths of three-quarter inch poly tubing lengthwise. Make sure you leave 20’ sticking out of the pile. Label intake.

5. Bury the lengths in horse manure or bark mulch 2’ deep.

6. Repeat steps four and five until you have 20’ left of tubing. Run that down beside the 20’ that are sticking out of the pile.

7. Pressure test the tubing before completely burying the pile.

8. Bury the pile with 4’ of mulch. Make sure the Big-O piping ends are exposed.

Manifold and Bed Construction

1. Install 20’ of 1/2” tubing in each bed with 2” of both ends sticking out on the same side of the box.

2. Take a piece of 3/4” PVC pipe and add 3 T-connecters and 2 NPT couplers on the ends. Install 1/2” barb fittings.

3. Repeat step 2. You will need 4 manifolds in total. On 2 of the manifolds install 1/2” valves with barb fittings on them. These are your return manifolds.

4. Connect 3/4” tubing to the return manifolds. Long enough so they can drain into the 45 gallon drum (reservoir).

5. Plumb a circulating pump in to the drum. Hook that up to the line labeled intake going into the pile. Hook the other line up to a T-connector that connects to the two manifolds without the valves.

6. Hook up the beds to the manifolds.

Appendix D

Planting Recommendations

Terra Firma Farms - Recommended Varieties

Salanova
Salanova lettuce was commercially available in 2013. Spring mix is comprised of harvesting lettuces or greens at a baby stage; because of the tenderness it has a short shelf life. In contrast Salanova is harvested at a mature full head stage with the core cut out to fall apart into individual leaves. The denseness of the leaves increases the shelf life. A typical head of lettuce is comprised of about 50 leaves while Salanova can have up to 200 bite sized leaves. It has been the work horse of our salad green production in summer and has shown that it can tolerate the freeze and thaw cycles of our winters with the use of row covers and double layered greenhouse.

Rainbow Kale
Rainbow Kale is a cross between Lacinato and Redbor Kale. The leaves can show a lot of variation in the colour on the same plant, from dark green to a deep purple with green or purple stems. We harvested it at baby leaf stage to add to salad mix as well as larger leaves for bunching and braising mixes over an extended period.

Red Devil Beet
Red devil beet is a variety of beet grown specifically for salad green production. Its leaves are bright magenta in cooler weather and can fade into partially green leaves when temperatures increase. The leaves can be harvested over an extended period of time with larger sized leaves used in braising mixes. It grows very slow during cooler months but has rapid growth in March and April when temperature and daylight increase.

Flamingo Chard
Flamingo chard has very glossy leaves with striking neon pink stems that create a beautiful contrast to the salad mix. This variety grew very well for us from our February plantings. There was a high percentage of crop loss from our fall planted crops. We do not recommend growing this variety until February.

Vates Kale
Vates Kale is an open-pollinated variety which makes it an inexpensive choice for the larger quantities needed for salad production. It performed well in each of the February plantings. There were some germination issues as well as crop loss in our final year planting so it will be difficult to tell if it performs as well as Rainbow Kale.

Extended harvests and multi-stage harvesting from both varieties of kale, flamingo chard and red devil beets allowed us to have multiple products on our market table. We were able to sell an attractive salad mix, a braising mix, as well as bunches of chard and kale early in the season. This improved customer retention from previous years.

Recommended Planting Dates

Survival of February planted crops were high with maturity about 60 days after transplanting from a 3-4 week old transplant.

October plantings had a 100% crop loss in 2015/16 and 2016/17 with additional protection of Remay fabric. In the October 2017 planting over 50% of crop was lost in the single layer greenhouse and about 25% crop loss in double layer greenhouse. The higher survival rate is likely from the addition of a Dewitt Ultimate Overwinter Cover. The estimated days to maturity from this planting is 160 days.

Although much of the 2017/2018 crop survived the winter (with temperatures below -10˚C for extended periods), they remained dormant during the coldest darkest months. Considering the increased days to maturity from the early planting we see no advantage to planting in the fall over a February planting.

Terra Firma's Soil Recipe

1 bale peat moss

4 - 5 gallon buckets of perlite

2 - 5 gallon buckets worm castings

9 cups Gaia Green All Purpose Fertilizer