12-2007

Extending the Season for Sustainability in Utah

Britney Hunter
Utah State University

Extending the Season for Sustainability in Utah

by

Britney Hunter

Thesis submitted in partial fulfillment of the requirements for the degree

of

DEPARTMENTAL HONORS

in

Horticulture in the Department of Plants, Soils, and Climate

Approved:

Thesis/Project Advisor
(Brent Black)

Departmental Honors Advisor
(Jennifer MacAdam)

Director of Honors Program
(Christie Fox)

UTAH STATE UNIVERSITY
Logan, UT

Fall 2007

Extending the Season for Sustainability in Utah

By Britney Hunter

Undergraduate Honors Thesis

Utah State University

December 2007

Abstract:

The importance of providing fresh produce on a local level is becoming a widespread consideration among people concerned with the character of their food. For regions without an opportune growing climate, extending the growing season can drastically advance productivity. High tunnels are one way to effectively and profitably extend the growing season in cold climates. The benefits of growing in a high tunnel go beyond raising the temperature. High tunnels contribute to higher quality small fruits and vegetables. The benefits of growing in high tunnels have been explored in other states and could be exploited by Utah growers. Utah's climate could be advantageous to high tunnel production, and further research will provide a foundation for advancement. This article will discuss previous research findings and considerations for the future of high tunnel production in Utah. High value crops under consideration include: Raspberry, blackberry, strawberry, tomato, specialty greens, and cut flowers.

Table of Contents

List of Figures

For mindful eaters, the healthiest food at the market has shifted from organic to local. John Cloud pointed out in a recent article featured in TIME magazine that organic farming is becoming industrial-sized and remarkably similar to conventional agribusiness (1). Organic or not, the fuel needed to transport our food over long distances is as environmentally significant as growing eco-friendly. "Locavore" has been designated word of the year by the Oxford University Press in 2007. The word describes a person concerned with the ecological impacts of growing and transporting food and strives to eat seasonally using only locally grown ingredients (2). There are now restaurants in California that commit to serving food originating within a certain radius of their establishment. It's easy for activists in California to commit to this idea, but there are fewer options for the rest of the country lacking an ideal production climate. A longer season would allow growers in cold northern climates to grow a wider variety of foods closer to the population that consumes the produce. The media's influence on the way people think about their food is good news for our local growers. Season extension technology could mean greater yield and profitability for farmers through this "niche" off season market area.

Introduction to Season Extension:

There are many strategies for keeping a young crop warm during the early part of the season. Floating row cover is one relatively inexpensive way of protecting spring crops. Floating row covers are typically a lightweight, spun bonded fabric made of polyester or polypropylene that lies directly over the crop with no additional support. The cloth can buffer the nighttime air temperature a few critical degrees giving the crop protection from frost injury. During the day, the cloth may need to be removed if the air temperature rises too high (3). Extremely thin floating row cover cloth exists that does not need to be removed during the day and will also serve as a method for pest exclusion (4). However, the cloth may cause injury to plant tissues if it gets blown around by the wind. Cultural practices such as using black plastic mulch and raised beds will increase soil temperature and drainage, also advancing the growth of young crops (3).

Figure 1. Low Tunnel in Argentina (5)

Figure 2. Small scale operating High tunnel (6)

Using "Tunnels" is a more structured way to extend the growing season. Low tunnels are a row cover with enveloping wire hoops and are generally covered with poly ethylene greenhouse plastic (Figure 1). Typical low tunnels are 2 to 3 feet tall (6). The structure provides temperature protection without damaging sensitive plant tissues like the row cover cloth which rests directly on the crop. High tunnels are designed to allow laborers and equipment to work inside, and range from 6 to 30 feet in height (Figure 2). High tunnels have been successfully used in other regions of the world and are gaining popularity in the United States. They can efficiently extend the season for a variety of crops including: small fruits, vegetables and cut flowers. Growers are still experimenting with new crops in high tunnels, each of which can have a unique benefit. Depending on the crop, high tunnels can extend the growing season by 3-5 weeks in both spring and fall (7).

Extending the growing season with high tunnels

The decision to utilize season extension technologies is based on a number of factors that present advantages and disadvantages. Important factors to consider include: Marketing and economics, temperature requirements, and pest management. The success of a high tunnel operation will depend on the crop and the ability to obtain a premium price for the produce.

Marketing and Economics

Advantages- Utilizing high tunnels is an exception to the "Get big or get out" idea of agriculture in America. The superiority of the product that can be grown makes it possible to capture a local market, and thereby profit significantly without turning into an oversized operation (8). A fresh marketing strategy might be necessary for expanding business; however, many growers with the potential to adopt a high tunnel system will already have an established market for their produce (9). Niche markets like restaurants and catering businesses are ideal targets because they demand high quality products. High tunnels effectively add value to fruits and vegetables by what Appropriate Technology Transfer for Rural Areas (ATTRA) calls "capturing and creating value" (8). ATTRA publishes cooperative guidelines for adding value to produce and many other practical subjects for growers. The high tunnel environment reliably promotes higher quality in various crops (10, 11, 12, and 13). Growing a higher quality product captures value by improving the product and marketing produce out of season creates value to the consumer when the supply of quality goods is very limited. High tunnels make production available when the market price of produce is high. Figure 3 (below) shows how the University of Missouri has used high tunnels to advance tomato production to a time when the average price per pound of large and medium tomatoes in the U.S is higher.

Synchronizing Production with Price:

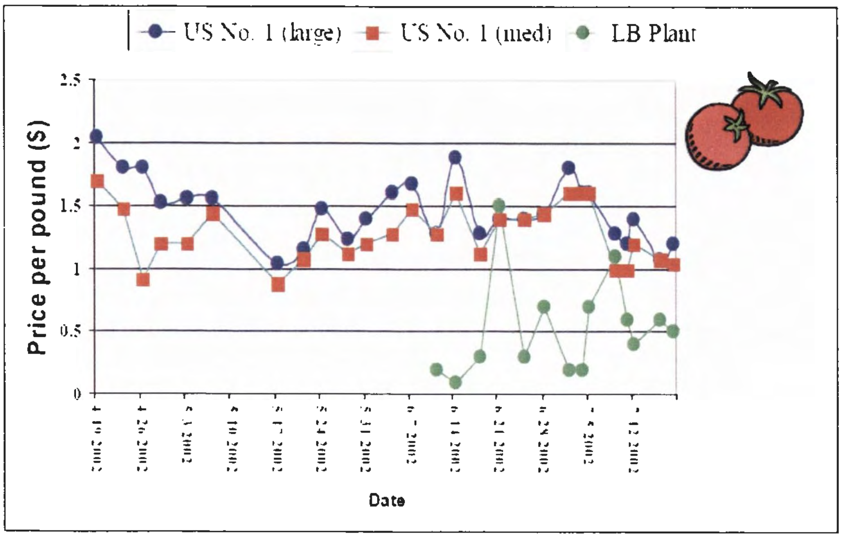

Figure 3. Average price per pound and off-season production reported by the University of Missouri. (14).

Disadvantages- Making the decision to integrate high tunnels into a farm operation will require extra funding and labor in the first year. Often the construction and initial growing season will be an intense trial and error experience. Utilizing previous research and resources will be a great benefit to the new high tunnel grower. A good development strategy could provide returns that cover these initial costs in two years of production (15). The cost of high tunnels is low compared to the potential value of off-season produce. The difference in production costs between using a high tunnel and growing in the field will depend on the complexity and size of the structure, on the crop grown and on the price premiums available. Additional labor hours will also be required to maintain the tunnels.

Examples of structure cost- The University of Kentucky estimated the cost of a 10' by 40' high tunnel to be $310 ($0.75 per square foot). These tunnels were constructed with schedule 40 PVC pipe, 4-mil greenhouse plastic, and lumber for the end walls. This estimation included the plastic mulch and drip irrigation tape, but it did not include the cost of construction labor (16). Researchers at Utah State University have experimented with a 14 x 42 foot high tunnel of PVC pipe framework construction, with an estimated cost of $420, or $0.71 per square foot (Drost, unpublished). Researchers at Penn State have a series of larger steel framed tunnels that are 17' to 30' wide and allow for machinery to operate inside. These steel framed tunnels are designed to withstand higher winds and winter snow loads, but are significantly more expensive ($2.75-$3.00/sq ft) (17). Any tunnel can also be built in a way to accommodate being moved from field to field, but some designs are more easily transported and reassembled. The type of tunnel selected will depend on the crop requirements and the size of the operation. The ability to provide additional management for the high tunnels should also be considered.

Temperature Protection

Advantages- The temperature in a high tunnel varies greatly depending on the outside temperature. The temperature inside can climb 30° F above the outside air temperature during the day, particularly on sunny days. This can be advantageous if quick ripening is desired. High light causes the soil to warm up and retain heat after the air begins to cool (18). Wind protection provided by the high tunnel makes it possible for the crop to retain heat in the area surrounding the leaf surface referred to as the boundary layer. Even if the surrounding air temperature is low enough to cause injury, calm air around the plant results in a thick boundary layer that protects the crown of the plant from damage. This is particularly beneficial considering the frequent crown injury seen in winter damage to strawberries (10). Using floating row covers inside the high tunnel will add additional protection (3). Further research could advance our understanding of this level of plant protection.

Disadvantages- High tunnels are designed to capture heat, and on a clear day a high tunnel collects heat very quickly. A smaller tunnel offers the advantage of keeping the heat closer to the crop, but the temperature can quickly rise above a desired level in sunny weather. Since high tunnels are passively cooled by cross ventilation, they require daily attention in respect to temperature control. The increase in temperature can cause fruits in the high tunnel to ripen quickly, but can also damage sensitive fruits with too much heat.

Pest Management

Advantages- Some studies have shown that the more controlled environment inside high tunnels facilitates organic management systems. Keeping the plants dry will aid greatly in the prevention of disease. However unique production issues must be addressed specifically to the regional climate. Organic insect and weed control should be easier if certain preventative measures are taken. Virus free, pest resistant cultivars should be planted and growth should be monitored regularly throughout the season. Pest populations as well as fungal diseases can be treated with organic methods if recognized before the problem is severe.

High tunnel systems may also integrate plastic mulch, which eliminates the majority of weeding for the grower. The structure can keep the majority of weed seeds from germinating inside. The areas that are not tilled and planted inside the tunnel are often used for walking space. Foot traffic and lack of water can suppress the weeds in the walkway as noted in the Utah State research high tunnels, leaving only small areas inside the tunnels that required weeding.

These areas were primarily along the edges and corners of the house. Flaming can be a very effective weed control inside the tunnel since spraying is unreasonable. Some hand weeding may also be necessary.

Disadvantages- The plants alone can produce enough excess humidity to coat the interior of a high tunnel, so adequate ventilation is critical. The closed microclimate of a high tunnel can cause populations of common greenhouse pests to develop where they would normally not be a problem in the field. Aphids, thrips and white flies are examples of a pest that can become a problem in a variety of crops. More information on controlling aphid and other pests can be found at http://plasticulture.cas.psu.edu/manual.htm.

High Tunnel Crop Profiles for Utah Production

In order to extend the knowledge provided by previous high tunnel research, conclusions should be made in regards to production in Utah. Utah may have unique advantages and disadvantages over different climates. For example, Utah has more sunny days throughout the year which could benefit production drastically; however, the effect of temperature shifts from high to low inside high tunnels is not fully understood. The low temperature extremes in Utah may be adverse to production, and high temperatures can cause damage to blossoms during pollination, for example. There are many different crop options for growers interested in using high tunnels which may thrive differently in a high tunnel. Below is a list of benefits and considerations that pertain to specific crops commonly grown in high tunnels. Fig. 4 shows a distribution of commonly grown crops in high tunnels according to the University of Missouri.

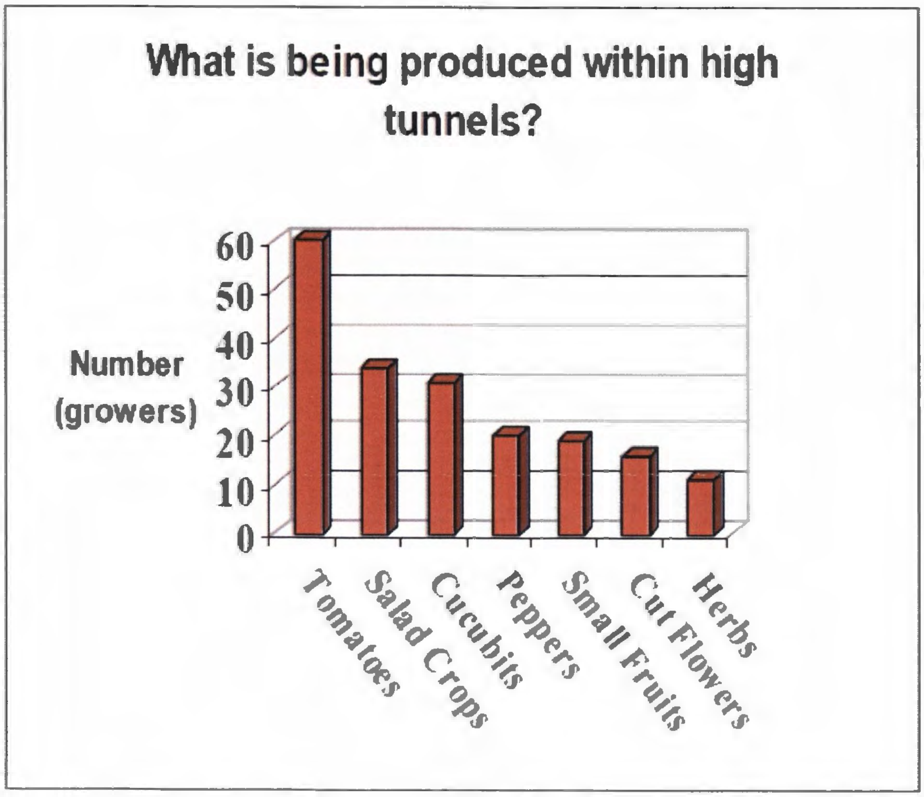

Figure 4. High tunnel crops and the number of Missouri growers engaged in high tunnel production (14)

High Tunnel Raspberry and Blackberry	
Benefits	
Increased Quality	Numerous studies have shown that brambles (raspberry and blackberry) grown in high tunnels may be superior in quality to field grown berries (11, 12, 13, 15).
Disease Reduction	A study conducted at Pennsylvania State University found that organic, pesticide-free production of blackberries and raspberries was relatively easy to achieve in a high tunnel (12). In humid climates in the eastern U.S. fungal fruit rots are common (21). Fruits in high tunnels with drip irrigation are kept dry which makes them less susceptible to fungal disease and greatly extends the shelf life. The hot, dry climate in Utah may reduce disease even further.
Extended Harvest	The high tunnel environment can promote early season fruiting as well as late season fruiting, and advance production approximately one month (20).
Profitability	Berries conventionally produced for the out of season market are typically of reduced quality because they must be shipped long distances and are highly perishable. This gives local growers with ripe produce a tremendous advantage with the ability to demand a premium price for their goods.
Considerations	
Construction cost	Raspberry and blackberry high tunnels can cost more than a simple PVC tunnel. A high tunnel built for raspberry production should be at least 9 feet tall. Taller structures will allow for larger side wall openings to improve air circulation. Larger structures may require additional support to accommodate large snow loads (12). Trellis structures may also be needed.
Pollination	The period of time when pollination can occur is short and insects must be present for good fruit set. (13)
More detailed information about high tunnel blackberries and raspberries can be found through the Department of Horticulture Website at Cornell University: http://www.fruit.cornell.edu/Berries/bramblepdf/hightunnelsrasp.pdf (20)	

Strawberry

Benefits	
Increased Quality	Strawberries produced in high tunnels are consistently better quality than field grown berries (10, 11).
Reduced Crown Injury	In Manhattan, Kansas field and high tunnel conditions for strawberry production were recorded from 2002 to 2004. The strawberries grown inside the high tunnels showed a considerable reduction in winter crown injury compared to the plants grown in the field (10). "In December, 15% of the field crowns were injured compared with 1% of the high tunnel crowns. As plants de-acclimated in March, 33% of the field crowns were injured compared to 5% of the high tunnel crowns." (10) This indicates a positive effect from the high tunnel microclimate during cold or mild winter temperatures. The average minimum temperature from December 2003 to March 2004 was 1 to 2 °C (~2-3°F) higher than the field temperatures. The lowest recorded temperature in this region between December and March is -5°F and the average minimum temperature is approximately 15°F. The average minimum temperatures are very similar to those observed in Northern Utah (Farmington, 22).
Extended Harvest	The high tunnel environment can promote early season fruiting as well as late season fruiting, and advance production approximately one month in spring and fall (10).
Profitability	Other berries supplied out of season are of greatly reduced quality because they must be shipped great distances and are highly perishable. Profitability will depend on the grower's ability to sell strawberries at an inflated price.
Considerations	
Temperature	Ventilation is critical and requires daily attention. Studies have shown that strawberry fruits in the sun can rise in temperature as much as 10° C above the air temperature (21). In Utah's high light conditions, and with the increased boundary layers found in high tunnels, midday heat load on the plants and developing fruit could become a problem.

More information about high tunnel strawberries can be found through the Department of Horticulture Website at Cornell University:
http://www.hort.cornell.edu/department/faculty/pritts/grnhouse.html (11)

Tomato	
Benefits	
Increased Quality	"In general, every tomato variety evaluated within a high tunnel has been equal to or better than that variety performance in the field." (23). Locally grown varieties can be selected more for taste and less for shelf life, improving the quality further.
Extended Harvest	In northern Utah it is possible to yield tomatoes approximately one month earlier than field grown tomatoes.
Profitability	High tunnels allow for early season production when the price and demand of tomatoes is high. "Synchronizing production with price" is the key element in profitability. (14)
Considerations	
Light	In Utah where there is high light intensity, a shade cloth may be needed to avoid sunscald on plants without an expansive canopy. Organically grown tomatoes often have a thinner canopy making the fruits more susceptible to sunscald.
Heat Stress	Root zone cooling techniques should be incorporated to avoid heat stress (24).
More information about high tunnel tomato can be found through the Department of Horticulture at the University of Missouri: http://www.hightunnels.org/images/Assets/Production%20of%20Tomatoes%20within%20a%20High%20Tunnel.pdf New York State Variety Trial: http://www.nysaes.cornell.edu/pp/faculty/dillard/pdf/SAREFinalReport.pdf	

Cut Flowers	
Benefits	
Increased Quality	Keeps rain and wind off delicate petals, longer stem due to less stress (wind), overall much better quality (25)
Extended Harvest	Early and late harvest possible for some cut flowers. Harvesting is possible in any weather. (25)
Profitability	The off season price premium and increased quality is what makes growing in a high tunnel profitable.
Considerations	
Season Extension	The quality of cut flowers grown in a high tunnel may be very good, but if the plants are in production at the same time as field grown flowers, the benefit is defeated. (26)
Temperature	Cut flowers may grow well in a high tunnel, but in colder climates certain cut flowers grow very slowly. Frost tolerant varieties should be chosen for climates with minimum temperatures of 29 F or lower. (27)
Marketing	
More detailed information can be found in the ATTRA Specialty Cut Flower Production and Marketing publication: http://attra.ncat.org/attra-pub/PDF/cutflower.pdf	

Specialty Greens	
Benefits	
Higher yields and quality	Spinach and other greens produced under a high tunnel generally yield more in less time. One study at the University of Kentucky found that a small high tunnel could double spinach yields compared to spinach outside the tunnel (28).
Considerations	
Temperature	Utah's **high light causes temperature** extremes within the high tunnel, and high temperatures make greens more susceptible to bolting. Low temperatures can cause freeze damage to plant tissues. Plants that are hardened off may withstand freezing temperatures.
More information can be found through the University of Kentucky at: http://www.uky.edu/Ag/Horticulture/masabni/PPT/hightunnel.pdf	

Utah State University has been working on research involving Lettuce and other specialty greens. Specialty greens are one of a few crops that can be grown in the winter months under high tunnels. The purpose of this experiment is to assess the effect of light angle on specialty greens as well as compare above ground planting to in ground planting in regards to productivity. The towers used to position plants at different light angles allow for a greater number of plants per square foot than a ground planting. This experiment will provide valuable information about the effect of light and temperature fluctuations that occur inside the tunnel.

Materials and Methods

Inside a 42' by 14' high tunnel, tiered towers were fitted with gutters filled with a soilless media. This positioned the lettuce plants at varying heights and angles. Two towers facing east and west were compared to towers with a southern exposure. Several ground beds were also planted throughout the high tunnel for comparison. Plants were placed every 6 inches in all of the treatments. The towers that face south were fitted with 9 shelves making it possible to grow 6.7 plants ft^2. The ground beds only allow for 4 plants ft^2. The orientation of the plants (South, West, East, or Ground) defines a treatment. Three different planting dates were assessed for productivity in this situation from September to November. The different planting dates were set up to be harvested four times over the course of four weeks, but there was some variation in planting and harvesting times.

Figure 5. Utah State University Lettuce High Tunnel

Figure 6. Utah State University Lettuce High Tunnel

Results and Discussion

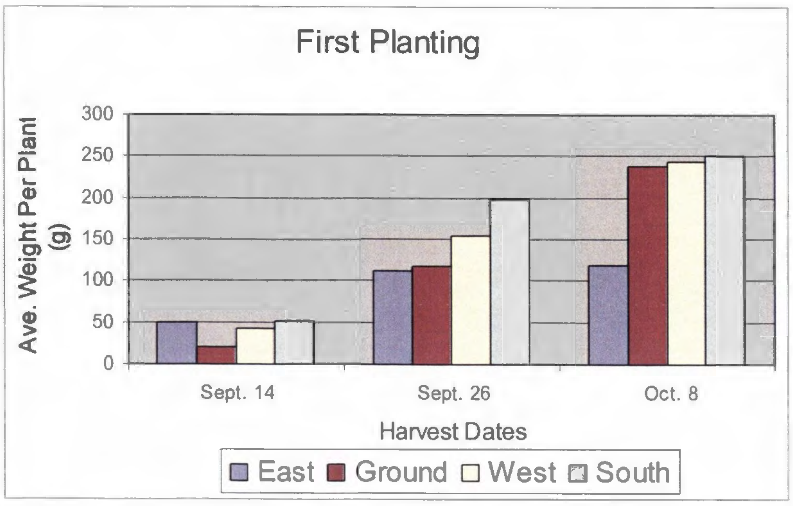

Figure 7. Effect of tower orientation on lettuce yields. Transplants were moved to the tunnels on September 3rd.

Each graph represents the yield from harvesting a set of plants from one planting date. Figure 7 indicates the south and west facing towers were the most productive initially, and on October 8th they were similarly productive to the ground bed. The east facing towers were the least productive, indicating that east light is limiting to production. The last harvest on October 8th, 2007 had an average temperature inside the tunnel of 12° C. The soil temperature stayed approximately 2° C warmer than the air temperature.

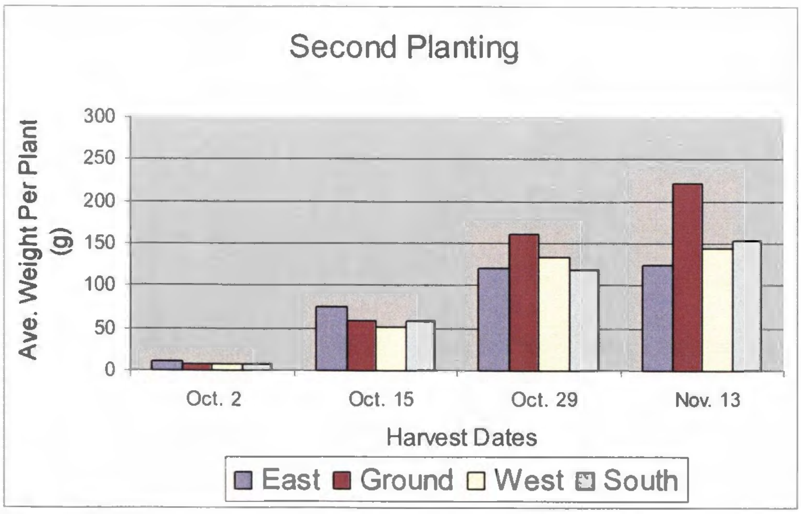

Figure 8. Effect of tower orientation on lettuce yields. For the second planting date, transplants were moved to the tunnels on September 14.

Figure 8 shows a decline in the productivity of the west and south tower treatments, while the productivity of the ground beds continues to increase. The result is likely due to cooling air temperatures. The ground is able to retain more of the heat that is captured by the tunnel; consequently, the ground stays warmer and the lettuce plants in the ground treatments grow larger. The soil less media in the tower treatments cools to air temperature at night and occasionally was frozen at the beginning of November which could account for the decrease in production. The last harvest on November 13th had an average temperature inside the tunnel of 4°C.

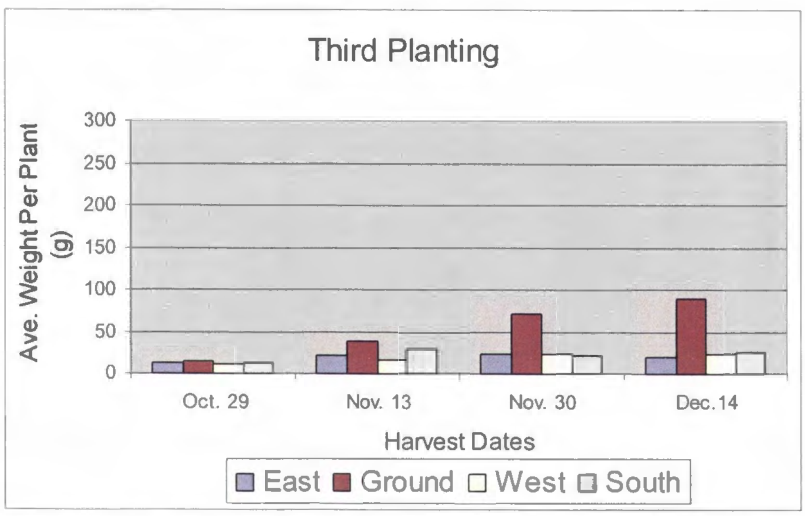

Fig. 9 Effect of tower orientation on lettuce yields. Transplants were moved to the tunnels on October 10.

The third harvest (Nov. 30th) in figure 9 shows a significant decrease in overall productivity, but also the most sustained yield in the ground plots. The soil in the towers was found to be frozen several times in November. Freeze damage was noted on the lettuce grown in the towers as well as lettuce grown in the ground starting in late November. Figures 7 to 9 represent observations made in the high tunnel. The average temperature for the harvest on December 14th was approximately 4° C. The lowest recorded temperature inside the high tunnel was -10° C. on December 6th. Though the treatments grown above ground in towers did not perform as well as the ground treatments, this method of production could be beneficial when temperatures stay above freezing. When temperatures drop below freezing, plants grown in the ground will be more productive. Row cover cloth should be used in all areas when temperatures drop below freezing, since freeze damage was found in the tower treatments as well as the ground treatments. Further experimentation will help to further identify optimal planting dates and temperature restrictions.

The Future of High Tunnel Production in Utah

There may be unique benefits to high tunnel production in the Utah climate. Utah has lower relative humidity and more sunny days in the winter months than eastern and Midwestern climates where previous high tunnel work was carried out. Lower relative humidity will decrease the chances for diseases to become problematic. Recent strawberry research in the United Kingdom has shown that light intensity is a critical factor in productivity. Shading of the plants reduced the yield of strawberries as much as 66% compared to the plants that were not shaded (29). However, the surplus light in Utah could also mean a serious heat load for high tunnel plants, which is known to reduce fruiting (30). Further research will more accurately demonstrate the advantages and disadvantages of high tunnel production in Utah. An in-depth market analysis and demographic assessment for different regions of Utah should be done to determine the potential scope of this industry. An individual operation may have customers that demand different products. Consistently earlier produce in Utah will mean more money stays in our community and less produce will be required from other states. Incorporating high tunnels is a promising option for improving the local food supply and moving toward greater sustainability.

There are many information resources available to growers, including from land grant university extension programs and The Appropriate Technology Transfer for Rural Areas (ATTRA). Penn State offers a widely used guidebook containing construction and production details for high tunnels. More detail on how to obtain the handbook can be found at http://plasticulture.cas.psu.edu/manual.htm.

Bibliography

1. Cloud, John. "Eating Better Than Organic." TIME. March 2, 2007. <http://www.time.com/time/magazine/article/0,9171,1595245,00.html>

2. OUP Blog. "Oxford Word of the Year: Locavore." Oxford University Press USA. <http://blog.oup.com/2007/11/locavore>

3. Butler Sr., Bryan R. and David S. Ross. "Extending the Production Season For Vegetables and Small Fruit." Maryland State Extension Factsheet. 1999. 2 Sept. 2007. <extension.umd.edu/publications/PDFs/FS760.pdf>

4. Ennis, Bonnie. "Organic Pest Controls That Work in the Vegetable Garden." Colorado State University Cooperative Extension. <http://www.coopext.colostate.edu/4DMG/PHC/organic.htm>

5. Salles, L.A., D.A. Sosa, and A. Valeiro "Alternatives for the Replacement of Methyl Bromide in Argentina."< http://www.fao.org/DOCREP/004/Y1809E/y1809e02.htm>

6. Fehrman, Chris and Luke Barrett. "Solar Greenhouses for Developing Countries." March 2005. <http://peacecorps.mtu.edu/resources/studentprojects/Solar_Greenhouses.htm>

7. Cornell University Cooperative Extension. High tunnel packet audio recording. <http://www.uvm.edu/sustainableagriculture/hightunnels.html>

8. Born, Holly and Janet Bachmann. "Adding Value to Farm Products: An Overview." ATTRA Publication. NCA. <http://attra.org/attra-pub/PDF/valueovr.pdf>

9. Adam, Katherine, Radhika Balasubrahmanyam, and Holly Born. "Direct Marketing." ATTRA publication. <http://www.attra.ncat.org/attra-pub/PDF/directmkt.pdf>

10. Kadir, S., E. Carey, S. Ennahli. "Influence of high tunnel and field conditions on strawberry growth and development." HortScience. Apr. 2006. v. 41, no. 2: p. 329-335. 2 Sept. 2007. <http://search.ebscohost.com/login.aspx?direct=true&db=agr&AN=IND43793387&site=ehost-live>

11. Pritts, Marvin. "Berried Treasures: Off-Season Production of Strawberries and Raspberries." Department of Horticulture Website at Cornell University. 1 Nov. 2000. 2. Sept.2007. <http://www.hort.cornell.edu/department/faculty/pritts/grnhouse.html>

12. Demchak, Kathy. "High Tunnel Bramble Production." Penn State University. 2005. <http://www.nevbc.org/2005_conference/sessions/brambles/high_tunnel_bramble_production.pdf>

13. Koester, Kurt D. "Winter Raspberry Production – High Quality, Premium Raspberries For The Off-Season Market Command Premium Prices." American Small Farm. Aug. 2003. <http://www.smallfarm.com/archive/2003/11November/12_11gh_raspberry_intro.htm>

14. Jett, Lewis W. "Improving Farm Sustainability with High Tunnels." Department of Horticulture, University of Missouri. <http://agebb.missouri.edu/sustain/whatnew/**hightunnel**s.pdf>

15. Heidenreich, Cathy et al. "High Tunnel Raspberries and Blackberries." Cornell University Departmet of Horticulture.. Publication No. 47. 2007. <http://www.fruit.cornell.edu/Berries/bramblepdf/hightunnelsrasp.pdf>

16. Ferguson, Amanda. "How to Build a High Tunnel." University of Kentucky. <http://www.uky.edu/Ag/NewCrops/hightunnel.pdf>

17. Haygrove. <http://www.haygrove.co.uk/introPage.asp?article=98>

18. Lamont, W.J., Jr. "Plastics: modifying the microclimate for the production of vegetable crops." HortTechnology. July-Sept 2005. v. 15, no. 3: p. 477-481. 2 Sept. 2007.

19. Stevens, Neil E. "Rots of Early Strawberries in Florida and Southern California." American Journal of Botany, Vol. 9, No. 4. (Apr., 1922), pp. 204-211. <http://links.jstor.org/sici?sici=00029122%28192204%299%3A4%3C204%3AROESIF%3E2.0.CO%3B2-2>

20. Ashcroft, Gaylen L., Donald T. Jensen, and Jeffrey L. Brown. Utah Climate. Utah Climate Center. 1992.

21. Jett, Lewis W. "Production of Tomatoes within a High Tunnel." Department of Horticulture, University of Missouri.

22. Moon, J.H., Y.K. Kang, and H.D. Suh. "Effect of Root Zone Cooling on the Growth and Yield of Cucumber at Supraoptimal Air Temperature." International Society for Horticultural Science.

23. Catie Rasmussen. "High Tunnel Cut Flower Production for Local Market Sales." Penn State Presentation. <http://plasticulture.cas.psu.edu/ppt/High%20Tunnel%20Cut%20Flowers.htm>

24. Esslinger, John. "The High Tunnel Demonstration." Southwest Pennsylvania Vegetable and Small Fruit Newsletter. Penn State Cooperative Extension. http://westmoreland.extension.psu.edu/Horticulture/Veg_Gazette/2005_DecVegNewsletter.pdf

25. Cavins, Todd J., John M. Dole, and Vicki Stamback. "Unheated and Minimally Heated Winter Greenhouse Production of Specialty Cut Flowers." Hort Technology. 2000. Vol. 10; 793-799.

26. Masabni, Joseph and Shane Bogle. "The high tunnel for cold season crops." UKREC. <http://www.uky.edu/Ag/Horticulture/masabni/PPT/hightunnel.pdf>

27. Fletcher, Mark J. et al. "The Effect of Light Integral on Vegetative Growth and Fruit Yield of 'Elsanta' Strawberry." ASHS press. 2002

28. Darrow, George M. The Strawberry. History, breeding and physiology. Holt, Rinehart and Winston. 1966.

29. Bewley, Matt. "Can the Northern Plains grow its own vegetables?" Agweek (Grand Forks, ND). 24 July 2007. 2 Sept. 2007. <http://search.ebscohost.com/login.aspx?direct=true&db=nfh&AN=2W62W64236552049&site=ehost- live>

30. Waterer, D. "Yields and economics of high tunnels for production of warm-season vegetable crops." Apr-June 2003. v. 13, no. 2: p. 339-343. 2 Sept. 2007. <http://search.ebscohost.com/login.aspx?direct=true&db=agr&AN=IND43633053&site=ehost-live>

31. University of Saskatchewan. "High Tunnel Project." <http://www.usask.ca/agriculture/plantsci/vegetable/vegetable/vhightunnel1.htm#lettuce2005>

Authors Biography:

Britney Hunter's love of plants sprouted while working for a small nursery in Holladay, Utah as a junior in high school. She was raised in Salt Lake City, Utah where she graduated from Cottonwood High in 2003. After a brief semester at the community college she fled eagerly to Utah State University to pursue a degree in Horticulture. While attending Utah State, Britney spent time working with professors in a variety of areas in Horticulture. She worked in the Integrated Pest Management lab and as an Undergraduate Teaching Fellow for the Woody Plant Materials class. Most recently she has been working on the Greenville Research Farm growing vegetables in high tunnel houses. Britney's involvement with the high tunnel research project gave her a reason to continue her schooling. After she graduates in December 2007 she plans to spend a semester traveling before returning to earn a Master of Science in Horticulture degree from Utah State University.