

Cool Season Specialty Crops in High Tunnels

High tunnels are relatively low cost, unheated structures that can be used to extend the growing season in cool climates, or provide opportunities for year-round production. High tunnels are less expensive and easier to maintain than greenhouses, but offer a protected environment for production of high value fruits and vegetables. The objective of this experiment was to evaluate the performance of a variety of different cool season crops for winter production in East Tennessee, and to compare the season extending capabilities of high tunnels versus an inexpensive low tunnel system. Plant growth, yield and quality were measured, as well as incidence of pests and diseases.

Season Extension Structures

Construction of three high tunnels was finished in mid-October, 2008, and this project was started soon after. The high tunnels are 30 x 48' with 14' high gothic arches (Griffin Greenhouse, Knoxville, TN). There is a double layer of 6 mil, greenhouse grade, UV treated polyethylene plastic and 6' roll-up sides. Polycarbonate sliding doors were installed on either end of the tunnels, allowing entry for a small tractor. Low tunnels were constructed using 10 gauge steel wire hoops, covered with Agribon Ag-50 frost blankets. This fabric is 1.5 oz per square yard, and protects plants to 24° F with 50% light transmission. The fabric was pulled over the hoops and anchored to the ground with landscape staples.

Weather Station Data

HOBO soil temperature loggers (Onset Computer Corporation, Bourne, MA) were used to record soil temperatures every 10 min. Soil temperatures were averaged from seven probes used in the high tunnels and eight probes used in the low tunnels. Outside air temperatures were measured using a Davis Vantage Pro 2 weather station, model 6152 (Davis Instruments, Hayward, CA).

Site Preparation

Prior to planting, the high and low tunnels were rototilled to a depth of 6" with a rotary tiller (Bush Hog, Selma, Alabama). Using a lawn spreader, soybean meal (7-2-1 NPK) was applied to both high and low tunnel areas at the rate of 4 lbs per 100 square feet (122 lbs N per acre). Irrigation was established with plastic drip tape, emitting water every 12" (Netafim, Tel Aviv, Israel). Tape was laid down in 9 rows with 2' alleys in between each row. Plots for each crop were 7' long by 2' wide and replicated 3 times (each high tunnel and corresponding set of low tunnels was a replication).

Crops and Varieties

Three different varieties of 11 crops, two varieties of Swiss chard and six varieties of lettuce were used in this study. All seed was untreated or certified organic. The crops and varieties were as follows:

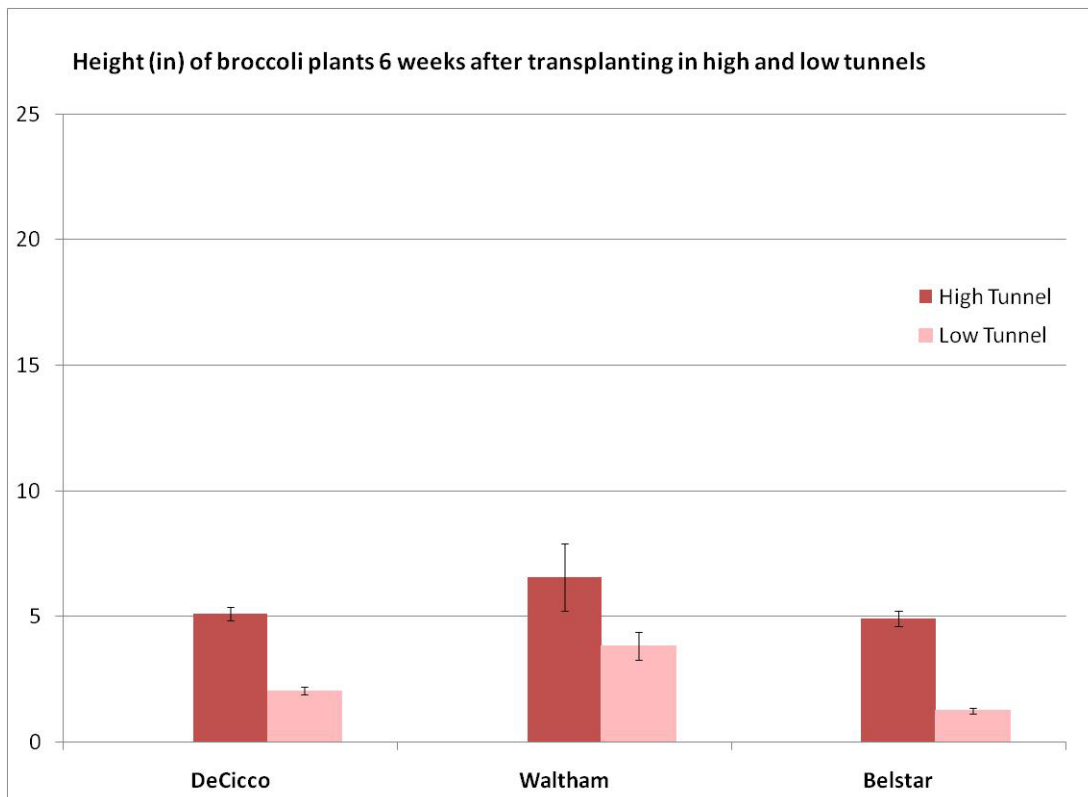
Broccoli ('DeCicco', 'Waltham', 'Belstar')
Spinach ('Butterflay', 'Bloomsdale', 'Matador')
Kale ('Lacinato', 'Red Russian', 'True Siberian')

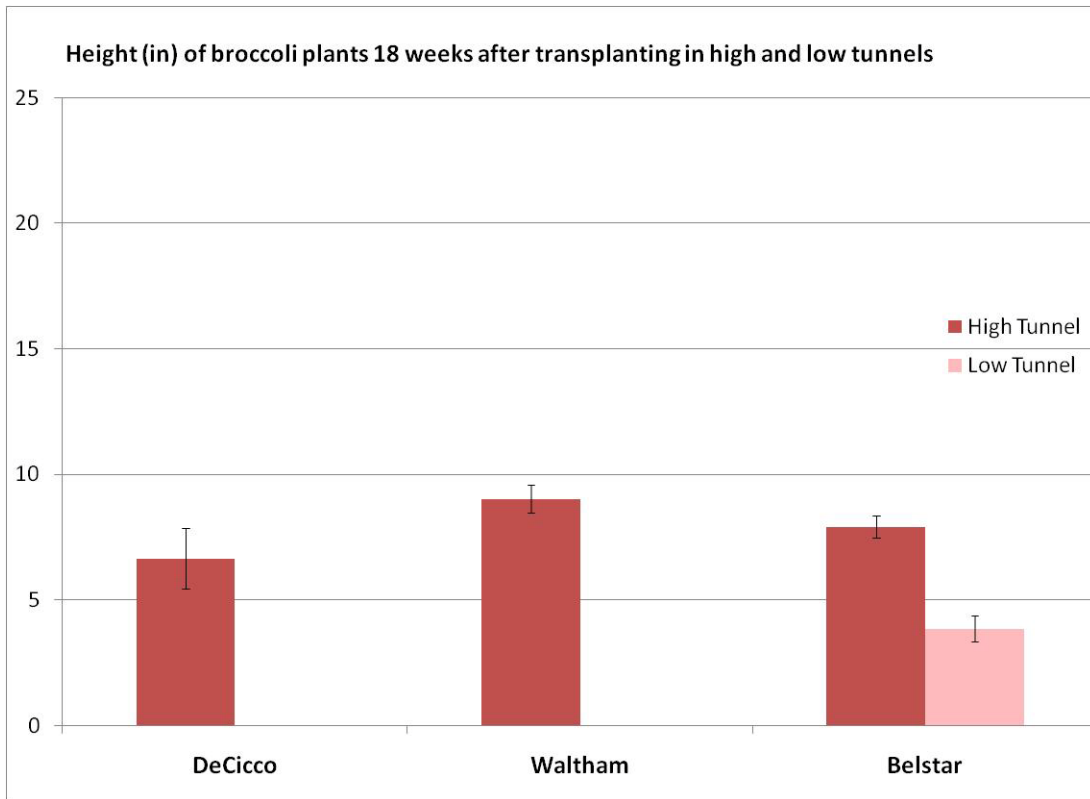
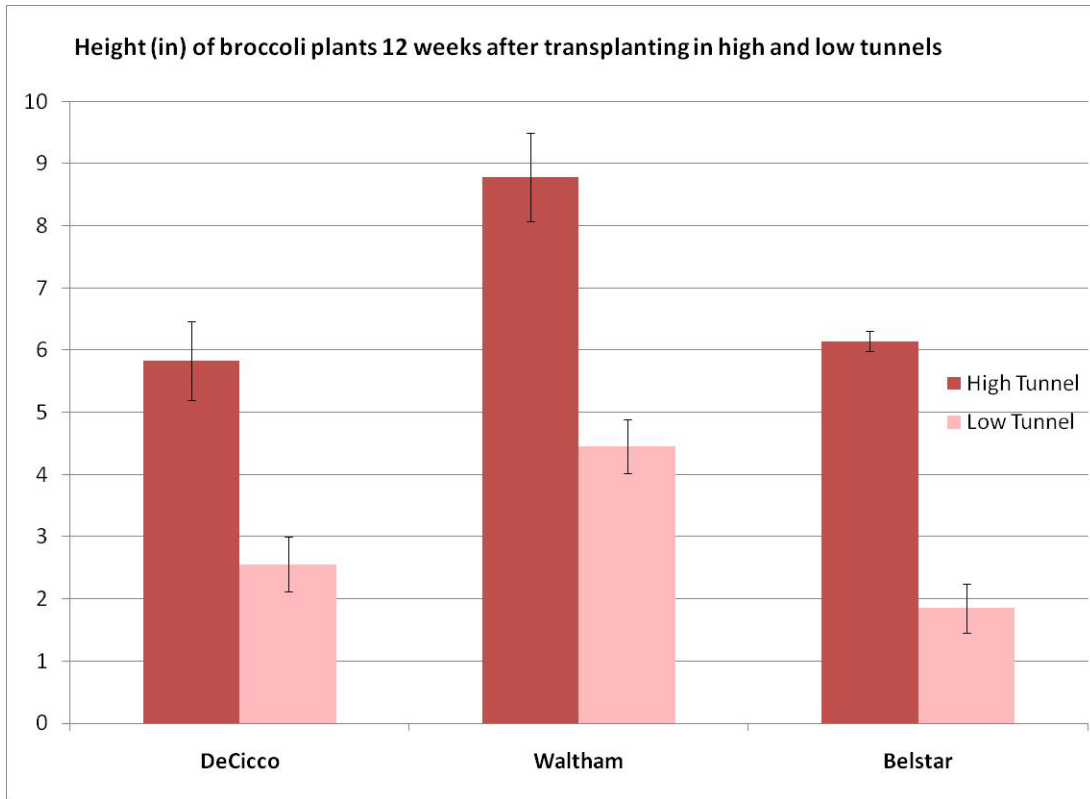
Lettuce ('Kweik', 'Winter Density', 'Brune D'Hiver', 'Ruben's Red Romaine', 'Drunken Woman Frizzy Headed', 'Red Oakleaf')
 Leeks ('Varna', 'Longfall', 'Blaugruner')
 Radish ('Round Black Spanish', 'Cherry Belle', 'Miyashige White Daikon')
 Cauliflower ('Grafiti', 'Odysseus', 'Cassius')
 Kohlrabi ('Dyna', 'Kolibri', 'Superschmelz')
 Beets ('Moneta', 'Golden Detroit', 'Chioggia')
 Sweet peas ('Mammoth Melting', 'Cascadia', 'Sugarsnap')
 Carrots ('Red Core Chantenay', 'St. Valery', 'Oxheart')
 Onions ('Mini Purplette', 'Evergreen'; 'Parade')
 Swiss chard ('Chadwick's Choice' and 'Glattersilber')

Broccoli, kale, cauliflower and leeks were started in the greenhouse on 7-Aug-08. Onions were started 3-Oct-08. All other crops were direct sown. Crops were planted in 3 different succession in the high tunnels and two successions outside in the low tunnels. The planting dates were 28-Oct-08, 20-Nov-08, 16-Dec-08 for the high tunnels and 3-Nov-08 and 15-Dec-08 for the low tunnels. Plant height and leaf width (cm) were measured 6, 12 and 18 wks after planting, and stands counted. Harvest yields were measured by weight, quality was rated visually, and taste and texture evaluated with sensory evaluations. Soil temperatures inside the high and low tunnels were measured every 10 minutes.

Results: Crop Performance

Broccoli



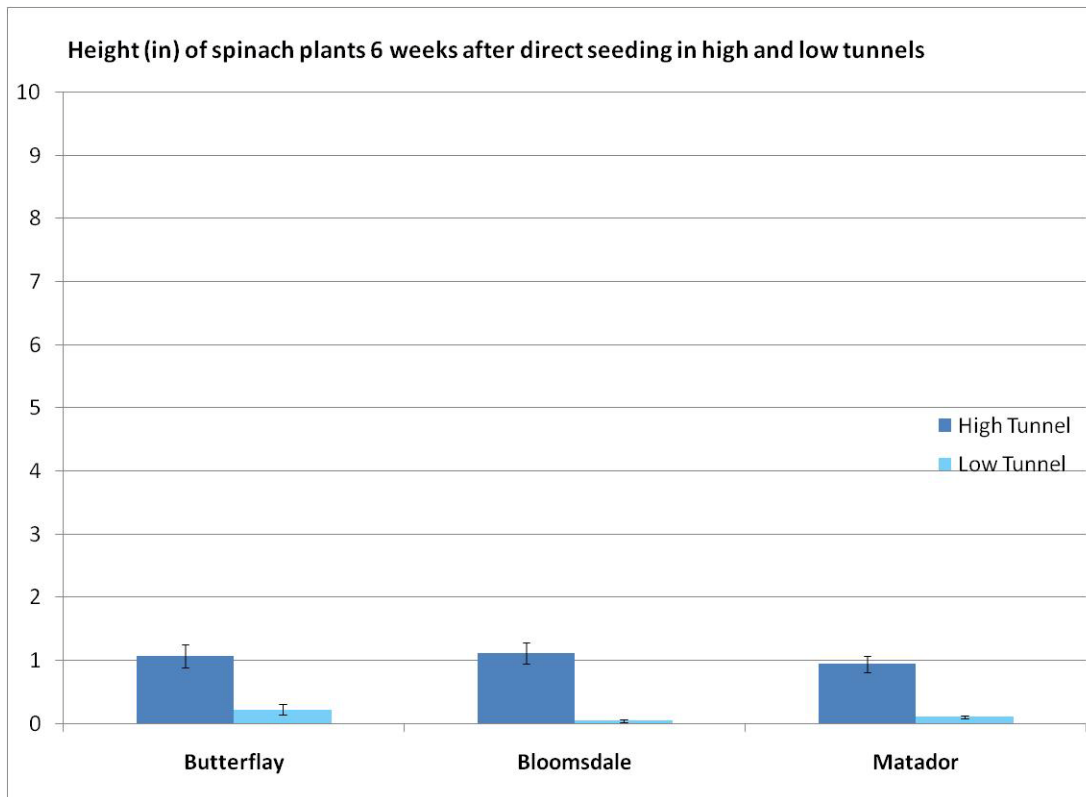


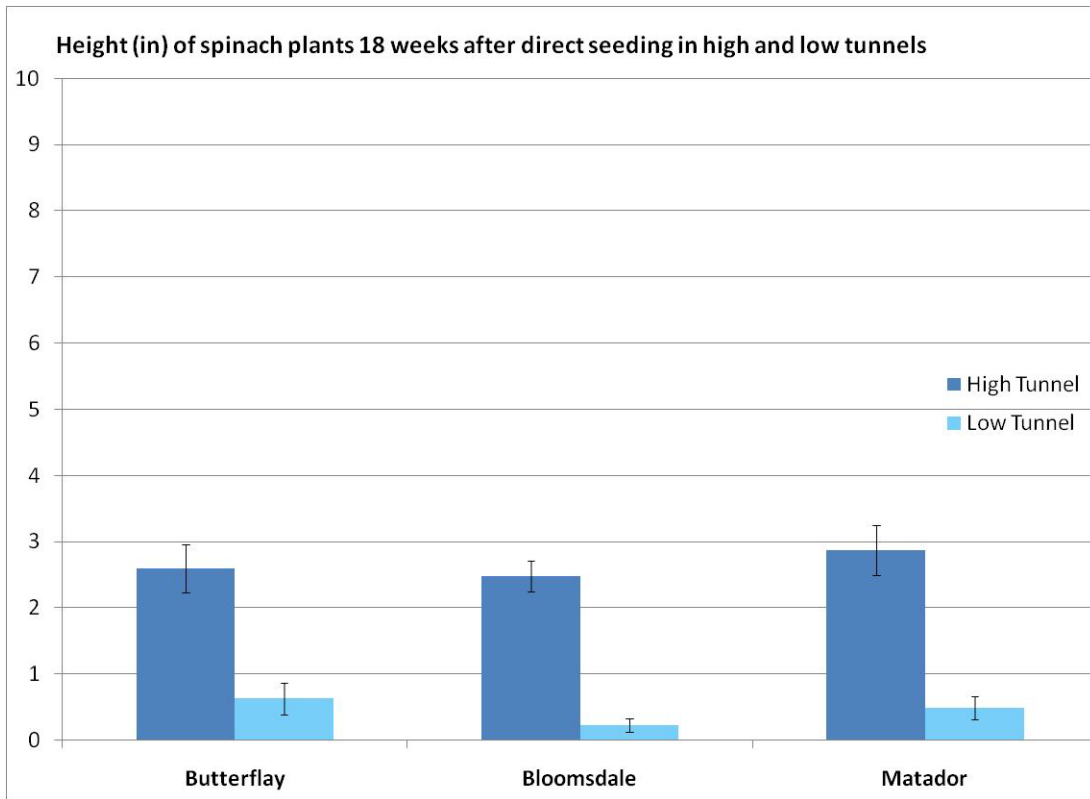
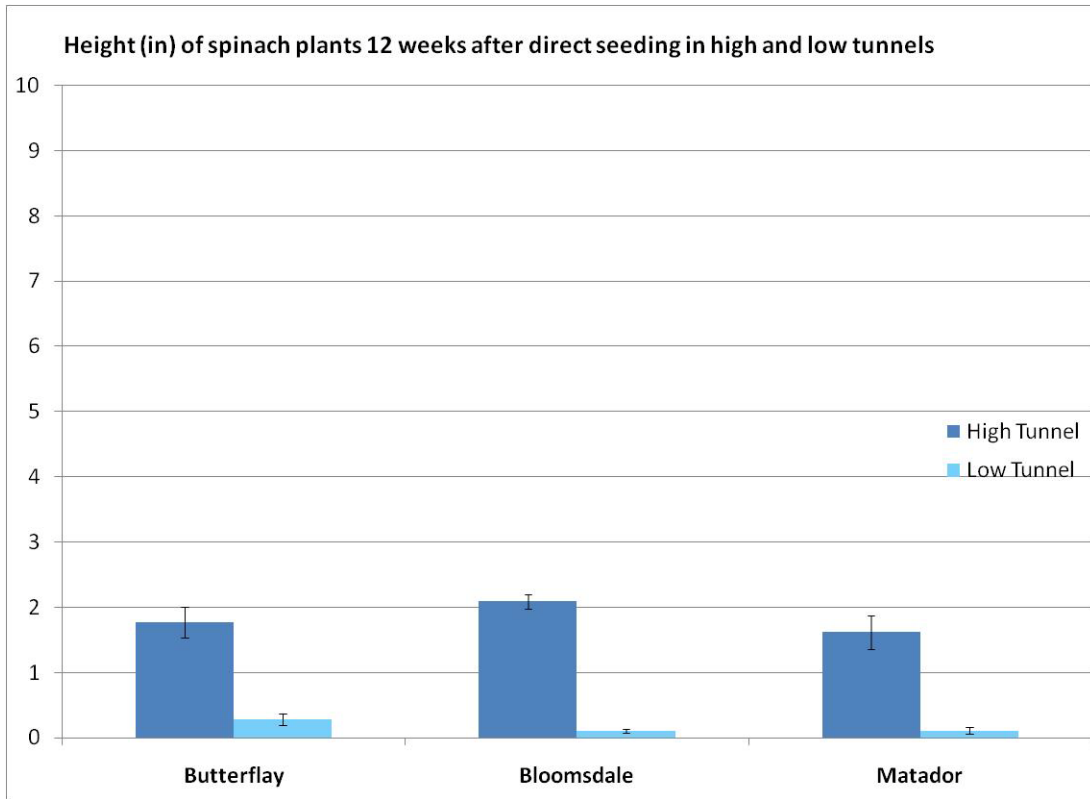
Summary

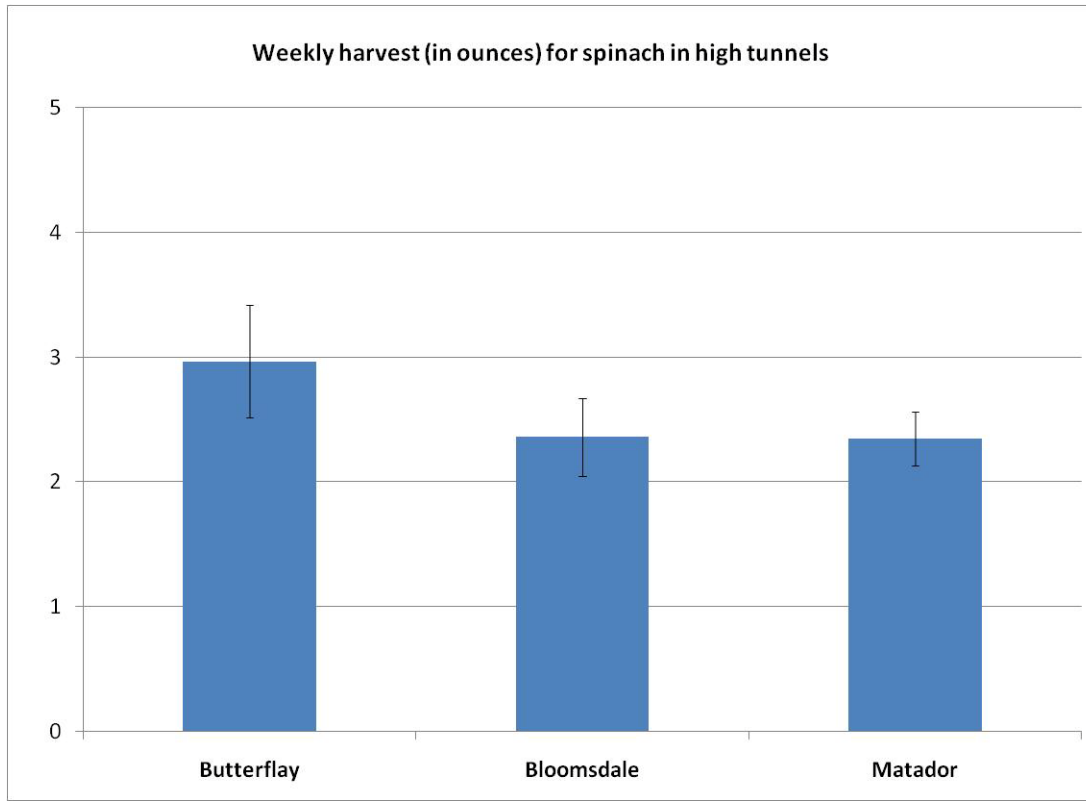
Each plot contained four broccoli plants of each variety. High tunnel broccoli plants grew quicker than low tunnel plants. The varieties 'DeCicco' and 'Waltham' did not survive in the low tunnels after 12 weeks, and only 3 out of 12 'Belstar' plants survived. In the high tunnels, 5 out of 12 'DeCicco' plants survived for 18 wks, compared to 10 out of 12 for 'Waltham' and 11 out of 12 for 'Belstar'.

A two-tailed t-test (JMP by SAS, 2009) showed differences in plant height for all varieties at all measuring dates ($P < 0.05$), except high tunnel-grown 'Waltham', which was not different from low-tunnel grown 'Waltham' at 12 wks ($P = 0.1674$). 'Belstar' was the only variety with marketable heads, and yields were low. Three heads from the high tunnels were harvested on 13-Mar-09, weighing 0.78 lbs, out of 12 plants total. Heads from remaining 'DeCicco' and 'Waltham' plants bolted. Broccoli plants in the high tunnels had low populations of green peach aphids. Under optimum conditions, days to maturity for 'DeCicco' is 48, 'Waltham' is 60-90 and 'Belstar' is 66-75.

Spinach



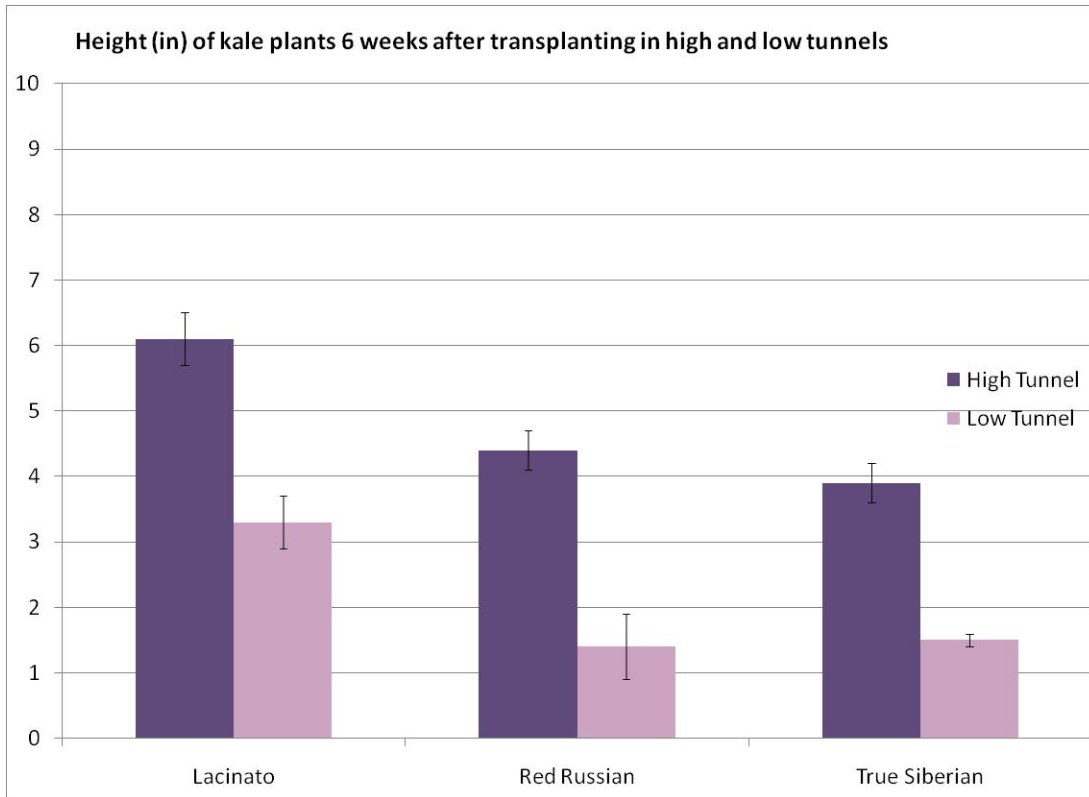


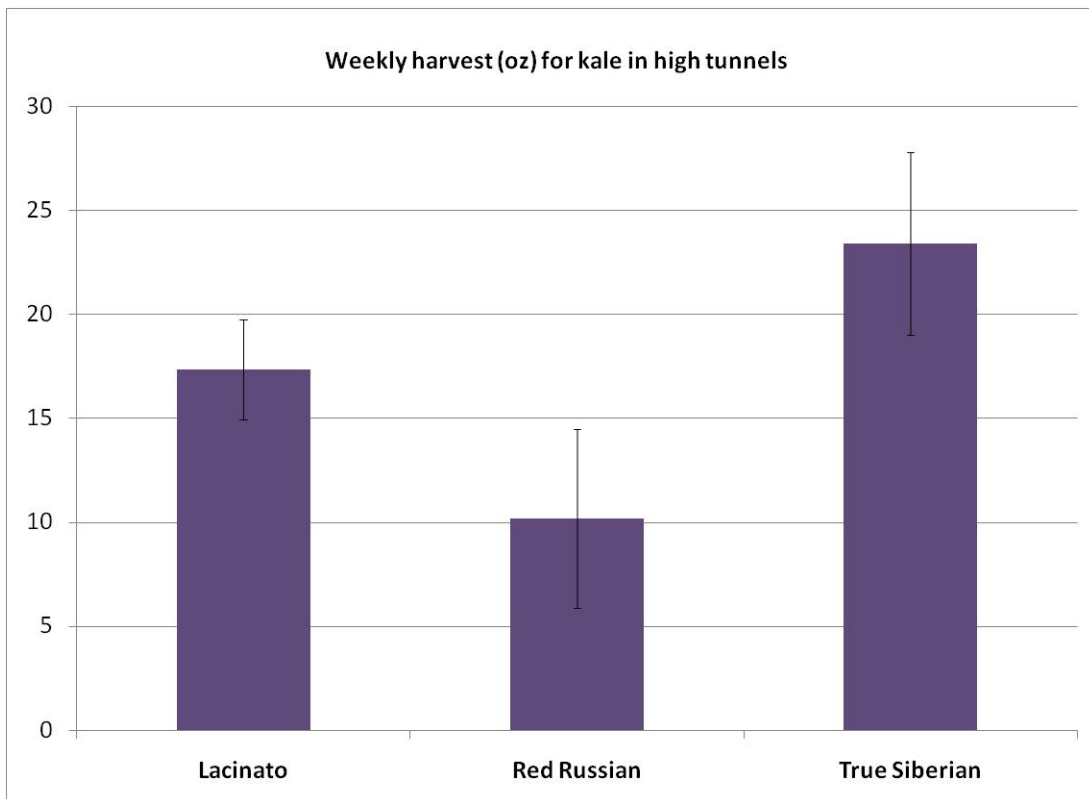


Summary

Spinach was direct sown in rows in the high and low tunnels on 28-Oct-08. High tunnel plants grew quicker than low tunnels plants across all three varieties. There was no difference in plant height between varieties at 6 ($p = 0.7238$), 12 ($p = 0.2494$) or 18 wks after planting ($p = 0.7045$). Overall, spinach grew well in the high tunnels and was harvested weekly over a 6 week period. There was no difference in the weekly yield between the three varieties ($p = 0.3409$). Total yields for 'Butterfly,' 'Bloomsdale' and 'Matador' were 2.93, 2.37 and 2.51 lbs, respectively. Plants in low tunnels were not harvested, as growth was reduced. Spinach in the high tunnels was high quality and not bitter. High tunnel spinach had occasional pest pressure from green peach aphids.

Kale





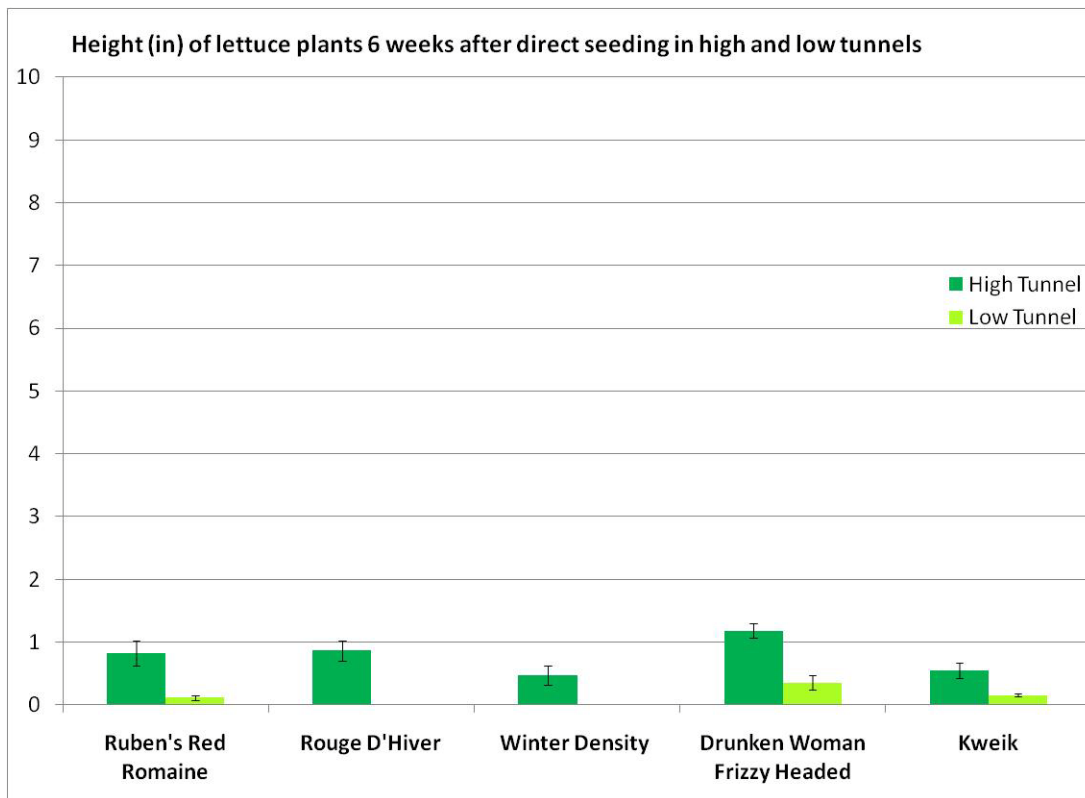
Summary

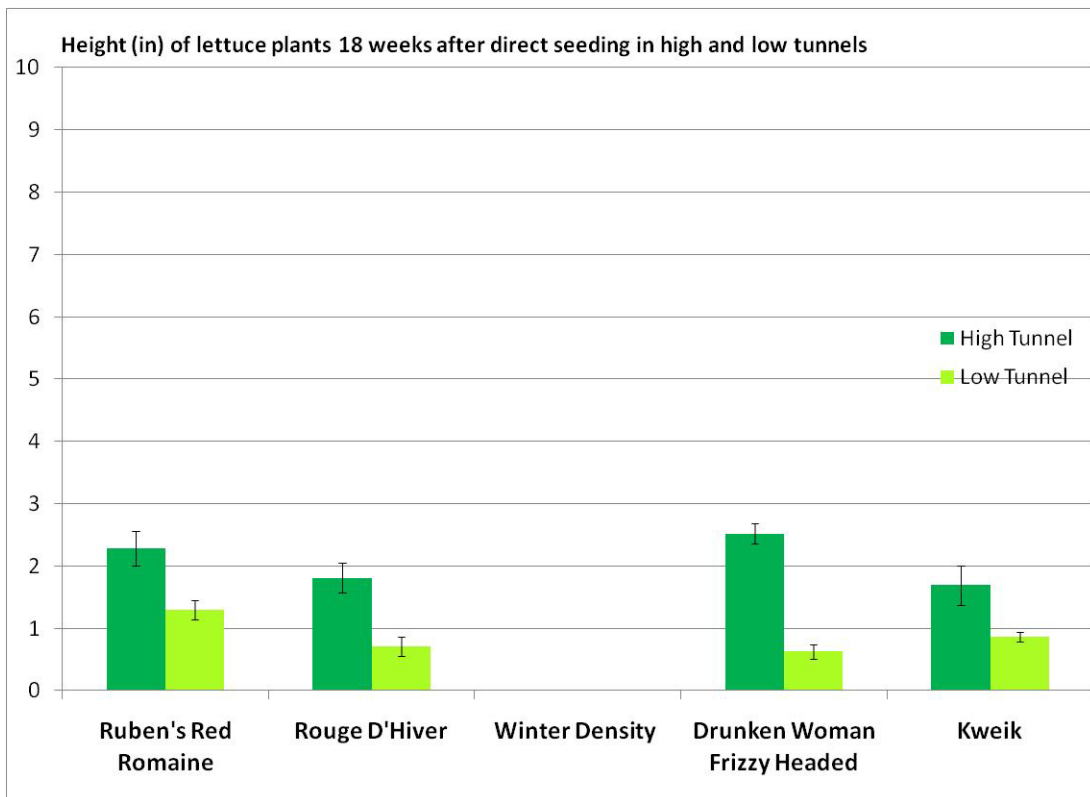
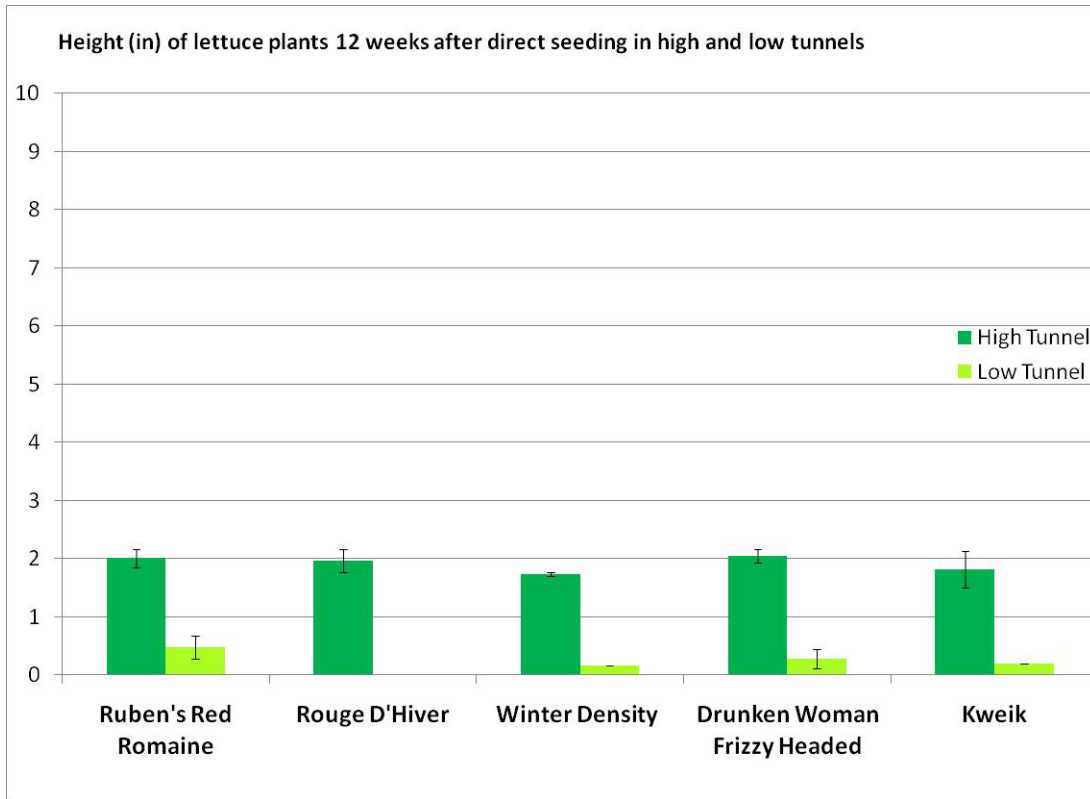
Each plot contained four kale plants of each variety. High tunnel plants grew quicker than low tunnel plants. All of the kale plants survived in the low tunnels, although growth was reduced and leaves were not harvested. Kale plants in the high tunnels, especially 'Red Russian', were very susceptible to green peach aphid infestation. Of the three varieties of kale, 'Lacinato' was the least susceptible to aphid infestation. All 'True Siberian' plants in the first replication were culled on 16-Feb due to heavy aphid infestation. Kale grown in the low tunnels did not have aphid problems.

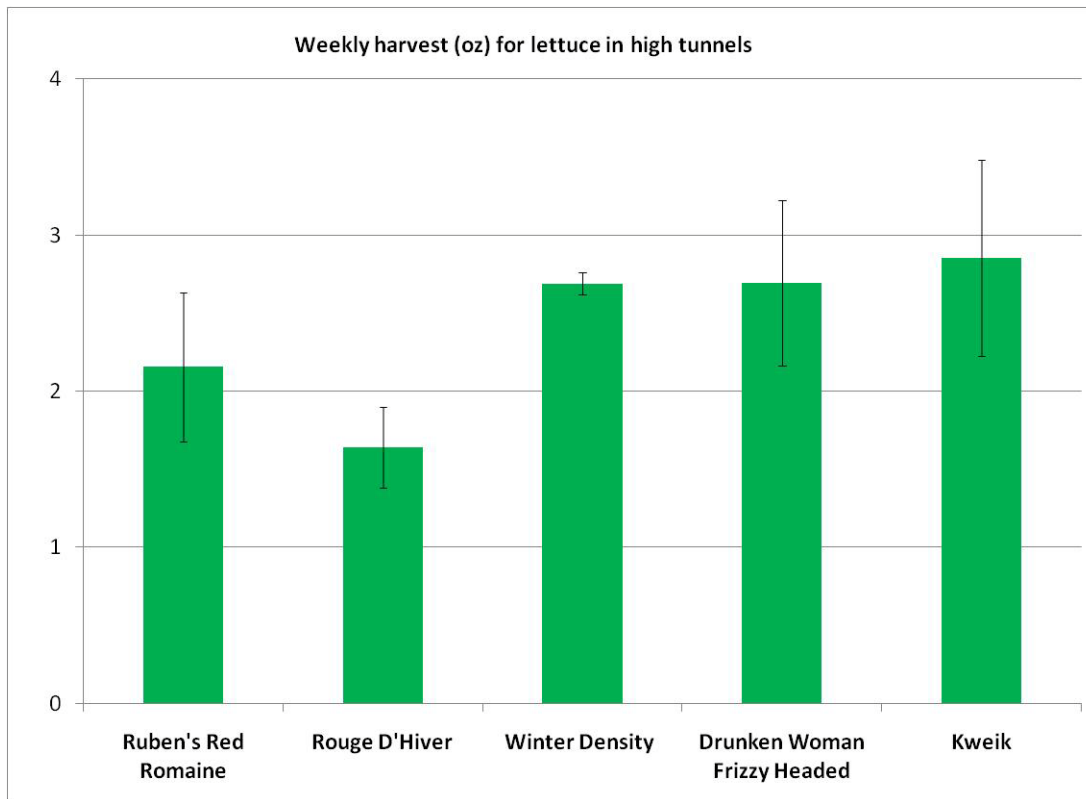
A two-tailed test showed difference in plant height for all varieties at all measuring dates ($P < 0.05$), except at 18 wks for the high tunnel -grown varieties at 18 wks ($p = 0.3174$). All high tunnel varieties were bigger than low tunnel varieties ($p < 0.05$).

Harvests for 'True Siberian' kale were the heaviest of the three varieties, and there were no differences in weekly harvest weights of 'Lacinato' and 'Red Russian' kale.

Lettuce





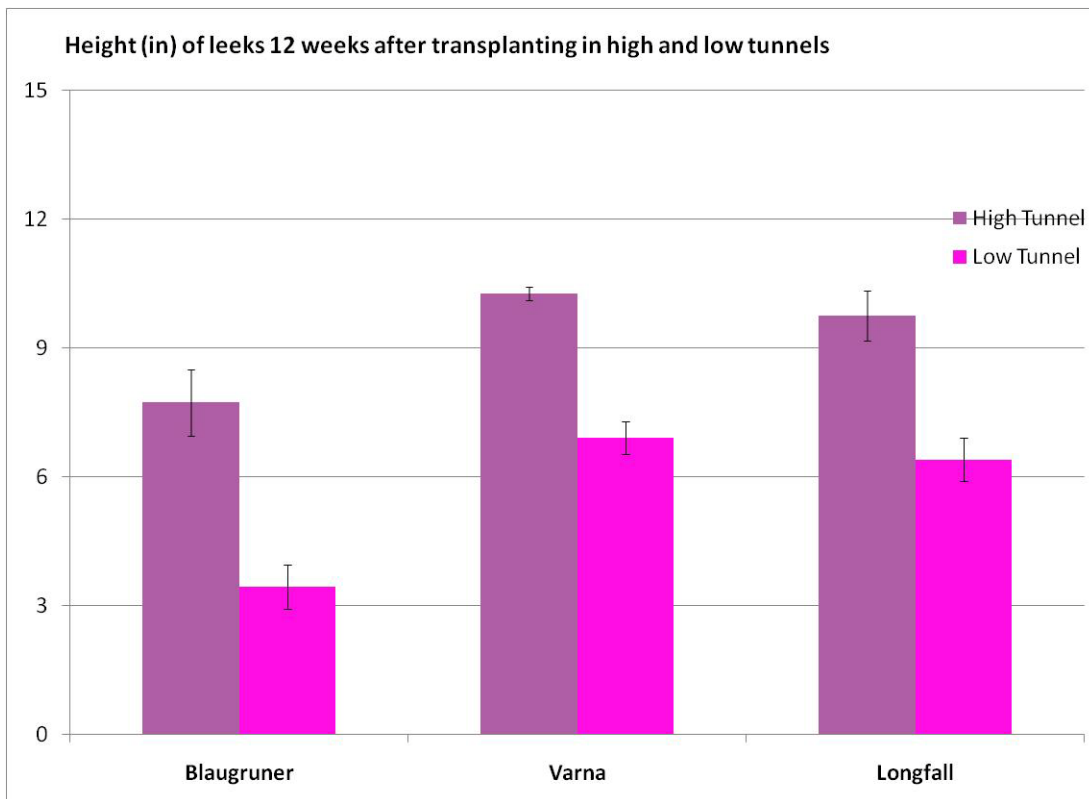
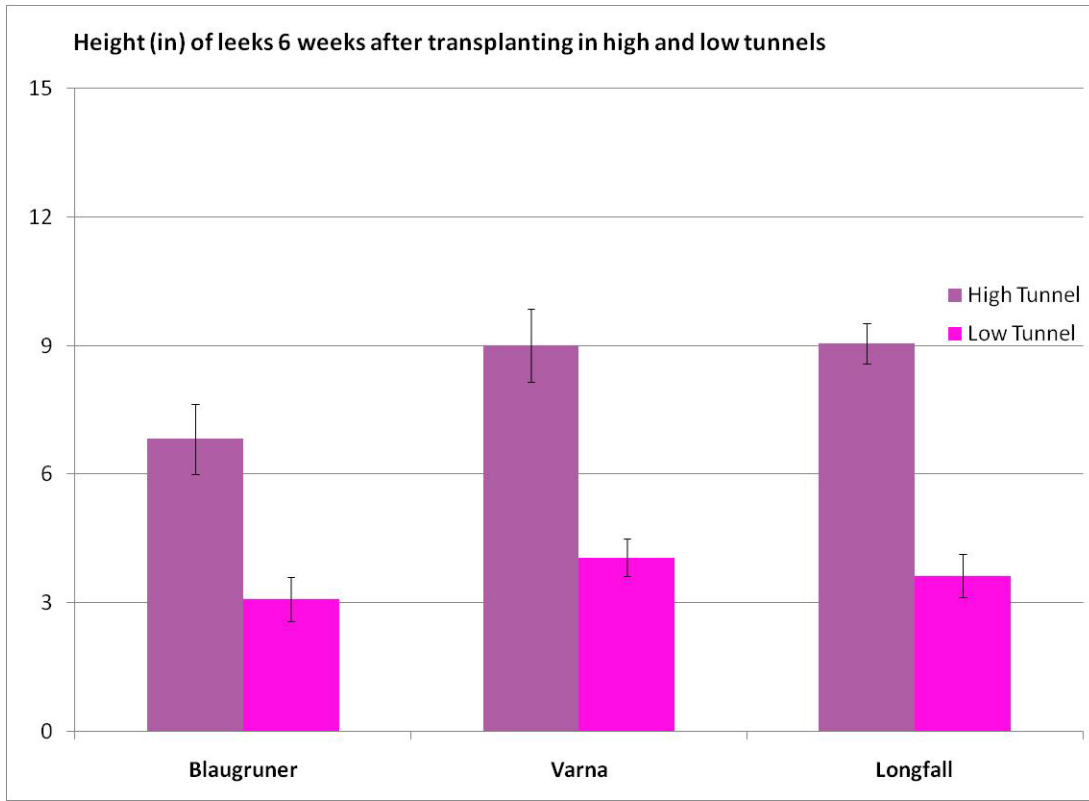


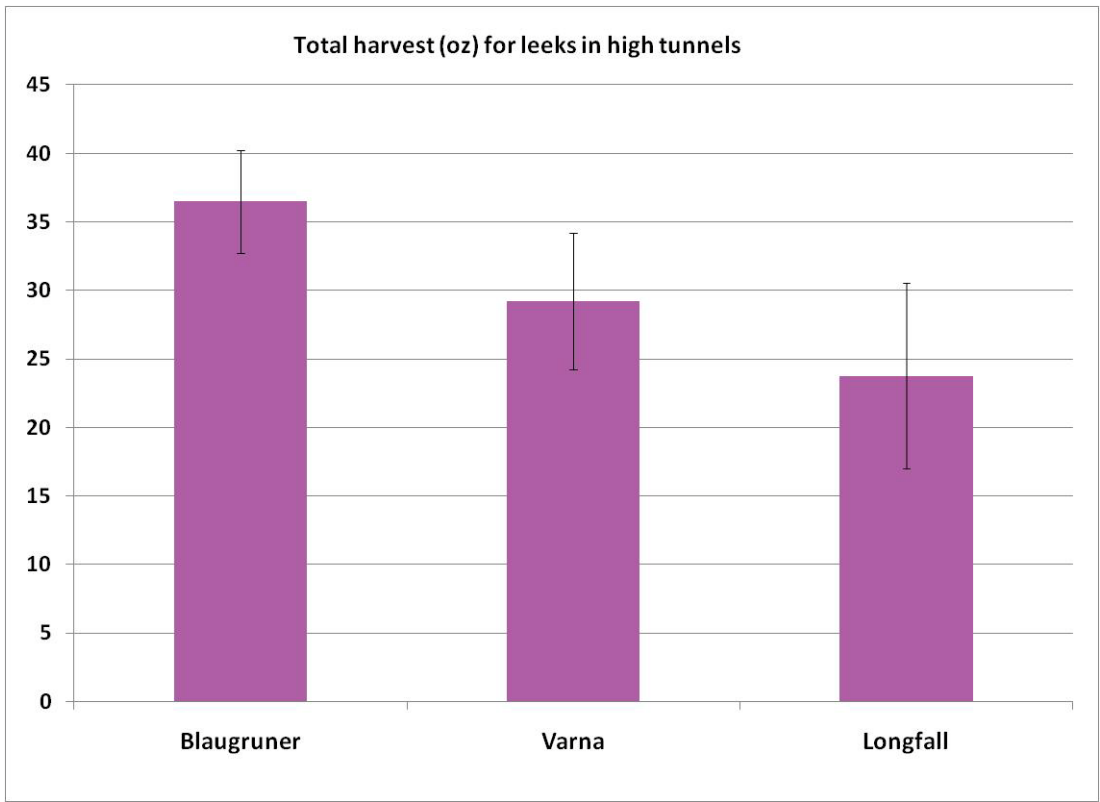
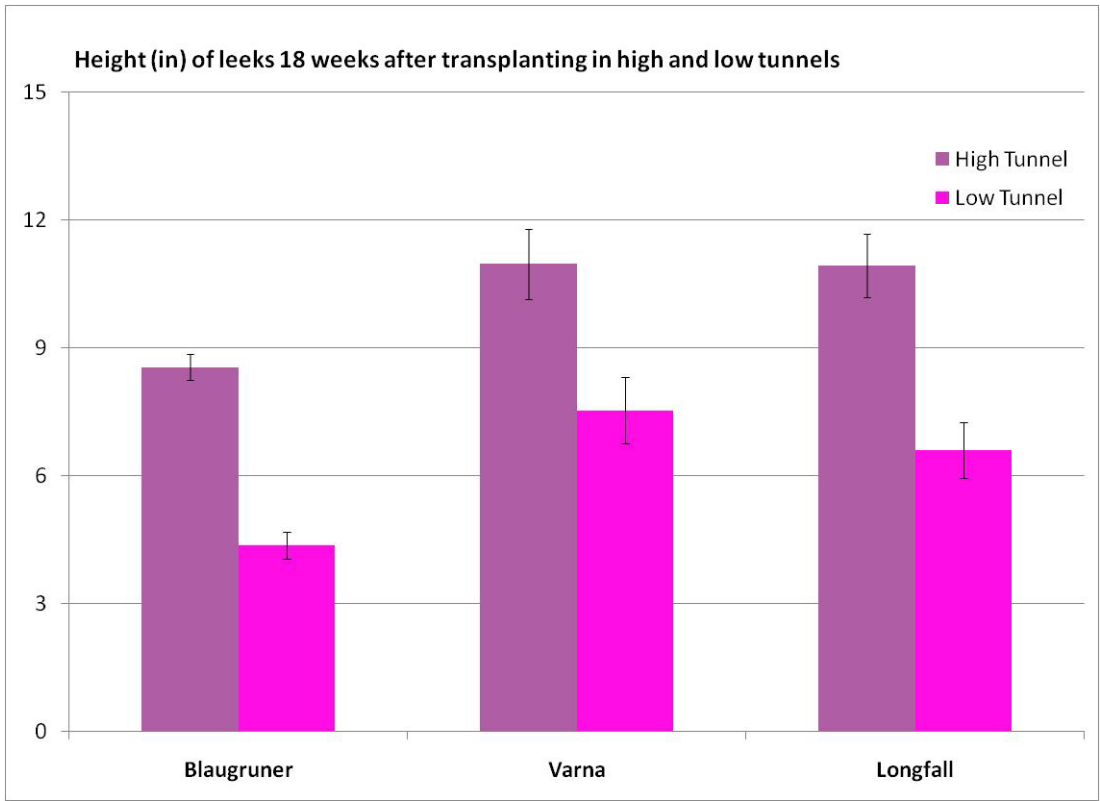
Summary

Six varieties of lettuce were sown, however, 'Red Oakleaf' seeds did not germinate, so were not measured. There were no differences between varieties in high tunnels across time. A two-tailed test showed no differences in plant height for all varieties at all measuring dates in the high tunnels ($p > 0.05$). In the low tunnels, there were differences in plant height at 18 wk ($p = 0.0143$), with 'Ruben's Red Romaine' being the tallest at 3.3 cm, and 'Drunken Woman Frizzy Headed Lettuce' being the shortest at 1.6 cm. All the varieties grown in the high tunnels were taller than the varieties planted in the low tunnels at all measuring dates ($p < 0.005$). 'Winter Density' lettuce measurements were not taken for the 18 wk measuring date, do to harvesting.

All varieties were harvested as young leaves, as they would be for a mesclun mix. Harvests were repeated until plants were determined too old, indicated by latex production which causes bitterness. As with the previous crops, plants in the low tunnels were not harvested due to reduced growth. Harvests in the high tunnels were lightest for 'Rouge D'Hiver'. All lettuce varieties had minor aphid pressure.

Leeks



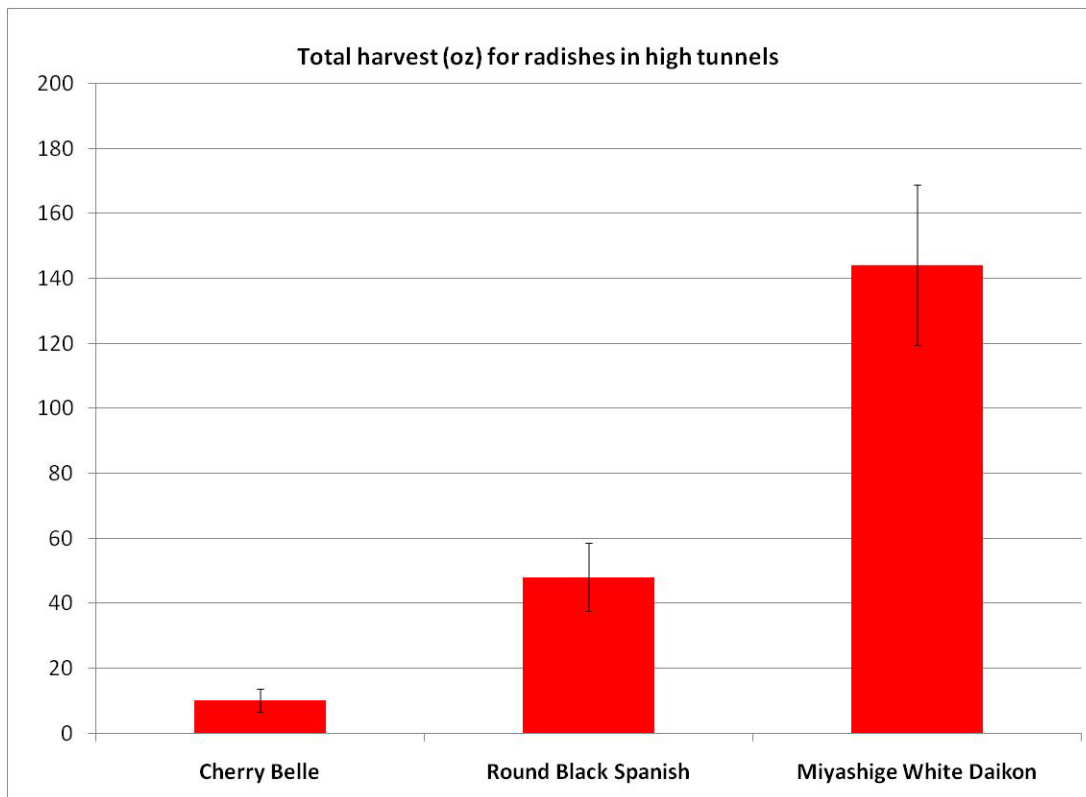


Summary

Leeks were measured by taking the height of the third leaf. At 18 wks, it appears that plants are shorter than the previous weeks. This is because, as leeks mature, the tips of the leaves turn brown. Plant height was used as an estimation of maturity for all crops, although diameter at the base of the plant would be a better estimation of maturity for leeks. Leeks grown in high tunnels were larger than leeks grown in low tunnels across time. 'Longfall' leeks in high tunnels were only slightly taller than 'Longfall' leeks in low tunnels at 18 wk ($p = 0.0509$). There was no height difference in variety for high and low tunnel-grown leeks at 6 wk ($p < 0.005$), but differences became apparent at 12 and 18 wk, with 'Blaugruner' being shorter than other varieties at both dates. Heights of 'Varna' and 'Longfall' were similar across time for both high and low tunnels.

Weights were measured on leeks that were harvested twice on 6-Mar-09 and again on 13-Mar-09, when base diameter was approximately 2 inches or more. There was a total of 24 'Blaugruner', 29 'Varna' and 24 'Longfall' leeks harvested out of a total of 36 total plants for each variety (12 per replicate). The remaining plants were undersized. Leeks were healthy and did not have disease or aphid problems.

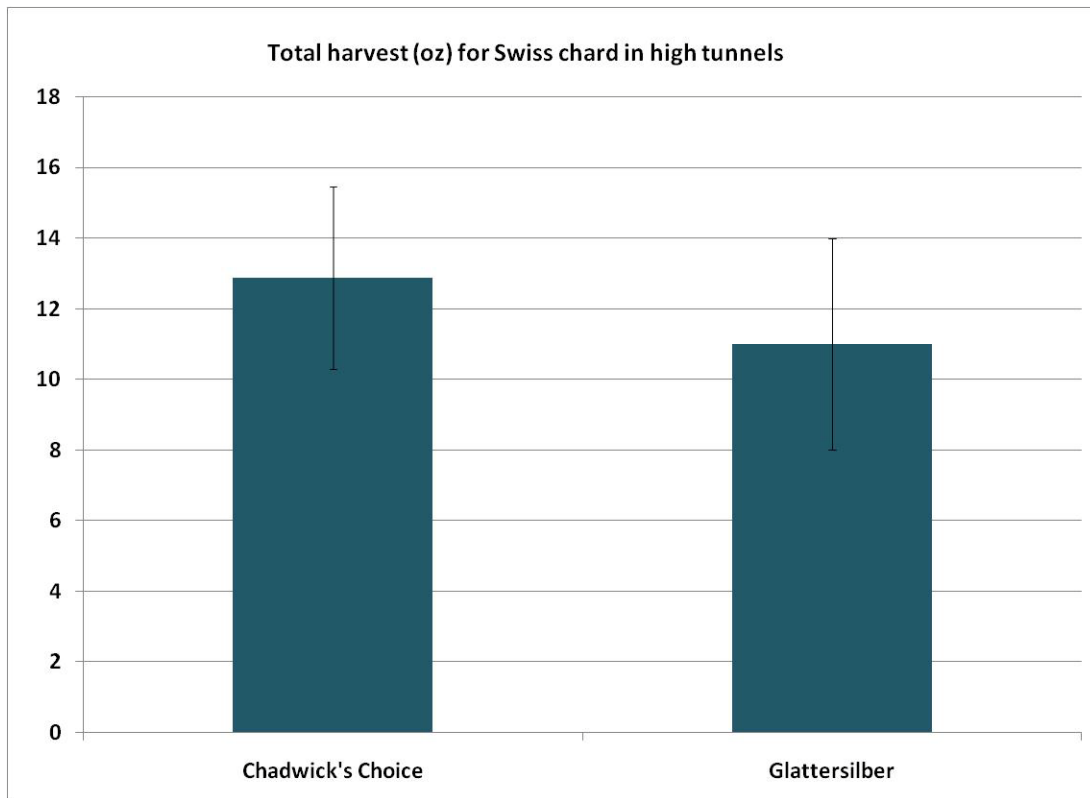
Radishes



Summary

Radishes that were direct sown in the low tunnels had poor germination and did not grow beyond the cotyledon stage. There were varietal differences between 'Cherry Belle', 'Round Black Spanish' and 'Miyashige White Daikon'. 'Cherry Belle' is a small, early maturing variety. Daikon radishes form large, long tubers. Leaf height and total harvest were different for all three ($p < 0.05$). 'Miyashige White Daikon' radishes were sub-optimal in size, and woody in texture. This may be a result of cool temperatures, or due to heavy, clay soils. The other two varieties were also woody in texture, but optimal size. Radishes had low aphid pressure.

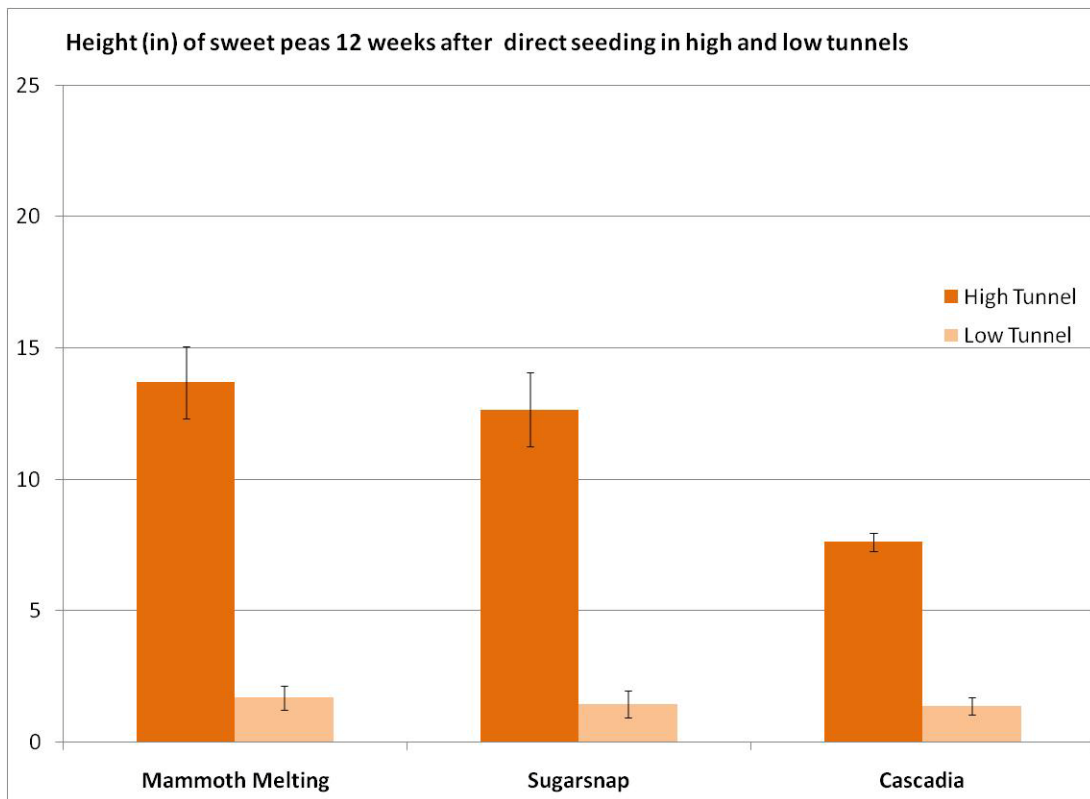
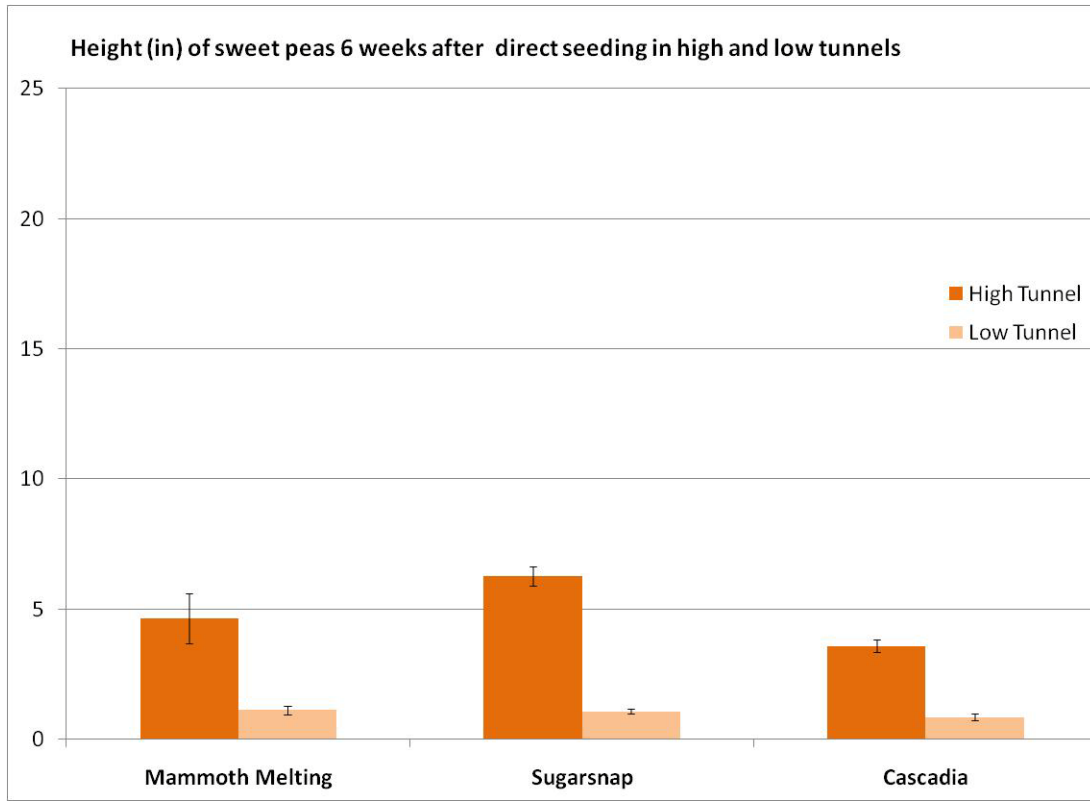
Swiss Chard

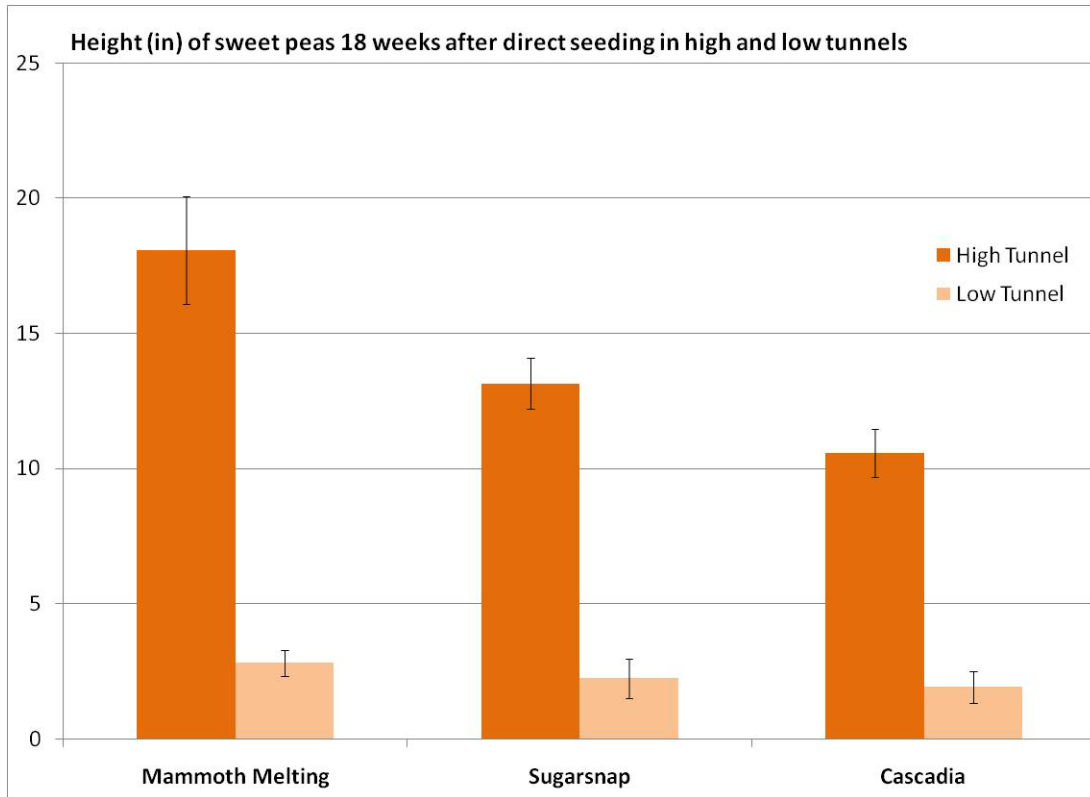


Summary

Two varieties of Swiss chard seed were direct sown in high and low tunnels. Germination in the low tunnels was poor, and most plants did not grow beyond the cotyledon stage. Harvests in the high tunnels were low due to reduced growth. Swiss chard was harvested in the high tunnels twice, on 6-Mar-09 and again on 13-Mar-09. There was no difference in harvests between 'Chadwick's Choice' and 'Glattersilber' ($p = 0.6609$).

Sweet peas

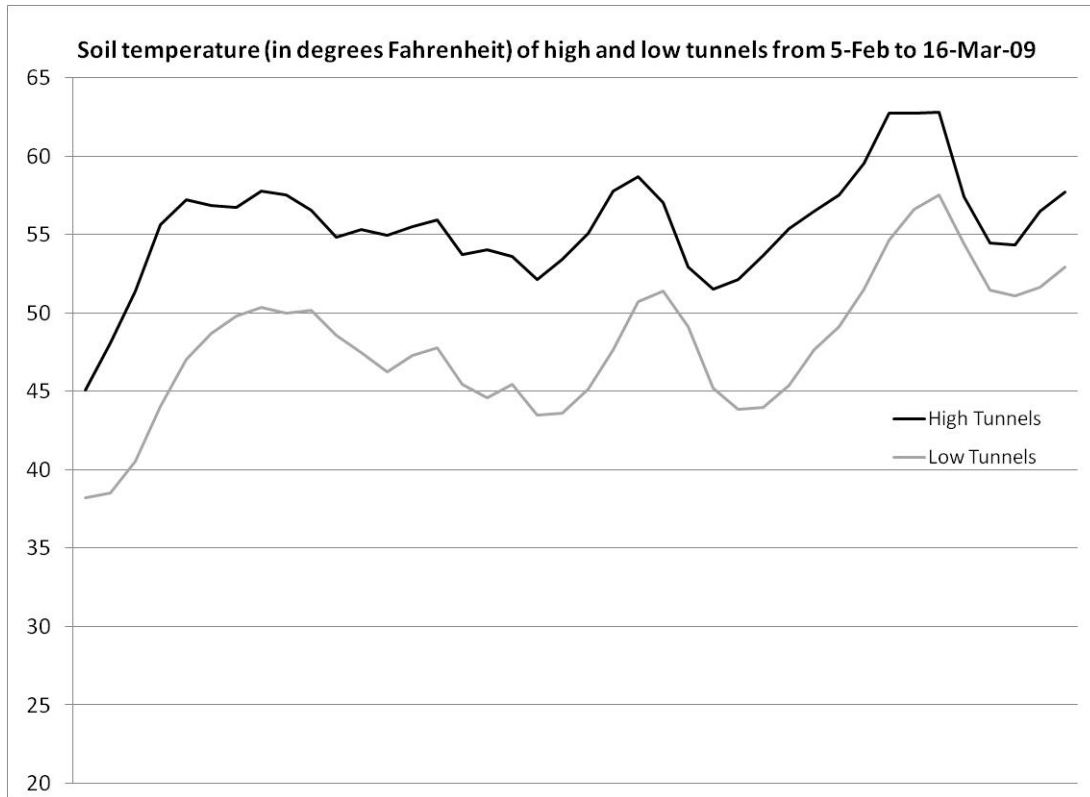


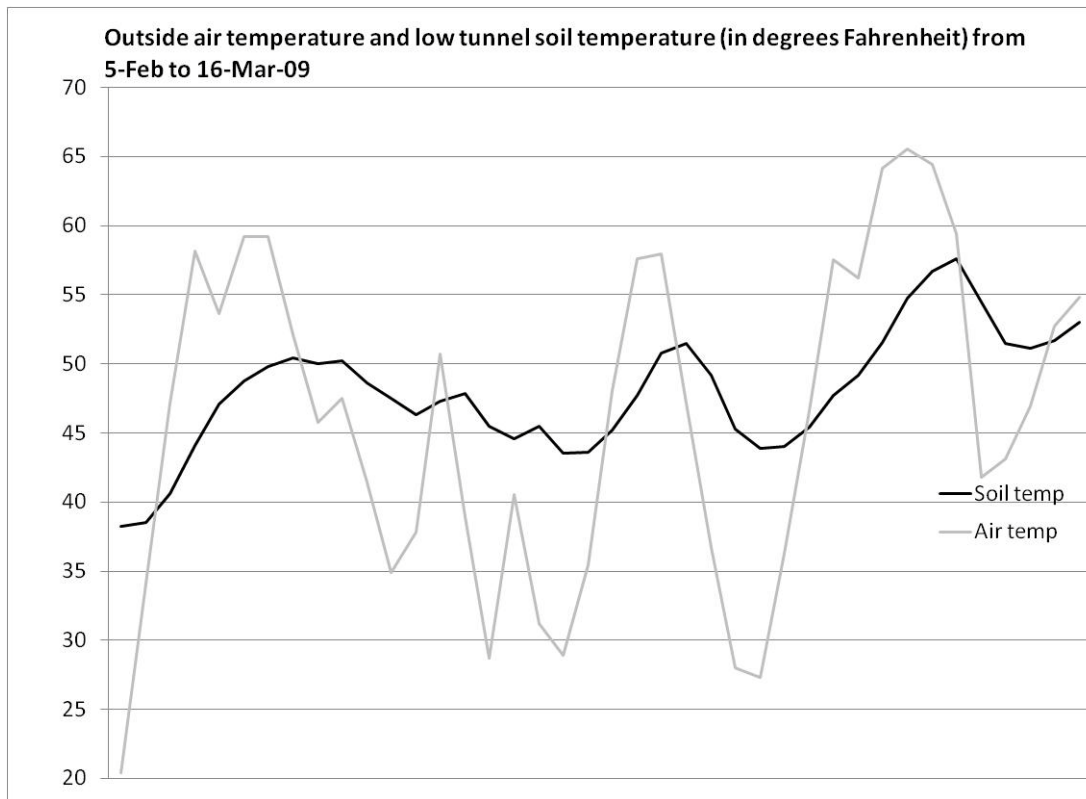


Summary

Three varieties of sweet peas were direct sown in high tunnels and low tunnels. Germination was lower in low tunnels compared to high tunnels, and there was no difference in plant height (cm) between the varieties grown in the low tunnels ($p > 0.05$). However, differences in height existed between all high tunnel varieties across all measuring times ($p < 0.05$), with 'Mammoth Melting' being the tallest, and 'Cascadia' being the shortest variety. Sweet peas inside the high tunnels had very few flowers, with no fruit developing for the duration of the experiment.

Results: Soil and Air Temperatures





Summary

The above graphs show average daily soil temperatures for high and low tunnels from 5-Feb to 16-Mar-09. The weather stations were started on 20-Nov-08. Logging in the low tunnels stopped after 1 wk, due to a short in one of the probes. The weather station was re-launched in the low tunnels on 5-Feb. The data show that soil temperatures in the high tunnels are approximately 10 degrees warmer than those recorded in the low tunnels.

The second graph shows outside air temperature and low tunnel soil temperature. Air temperature inside the low tunnels could not be recorded, but Agribon Ag-50 frost offers 8° F protection from frost. Air temperatures inside the high tunnels were not measured. This data is important, and will be included in future experiments.

Average outdoor air temperatures for the months of December, January and February were 41.9, 36.2 and 42.1°F, respectively. In December, there were 17 days below freezing (32°F); in January there were 22 days, and in February, there were 16 days. Of these, 53% of the days were below the 24°F protection offered by the frost blankets. Average indoor soil temperatures for the same months were 52.5, 49.1, and 53.8°F, respectively.

Conclusion:

This evaluation showed that crops grown inside the high tunnels were substantially larger in size and produced more harvestable material than those grown outside in the low tunnels from 28-Oct-08 to 13-Mar-09. Not all crops in the high tunnels were successful, however. Crops that did not do well, in terms of growth and maturity were: sweet peas ('Mammoth Melting', 'Cascadia', 'Sugarsnap'); beets ('Moneta', 'Golden Detroit', 'Chioggia'); carrots ('Red Core Chantenay', 'St. Valery', 'Oxheart'); cauliflower ('Graffiti', 'Odysseus', 'Cassius'); onions ('Mini Purplette', 'Evergreen'; 'Parade'). The optimum soil temperature for sweet peas is 55-65°F. Beets have an optimum soil temperature of 60-65°F. For carrots to germinate, soil temperatures of 75°F are required, but 60-70°F are good for carrot growth. Transplanted cauliflower grows best in 60-70°F soils, and transplanted onions grow best in 65-85°F. Poor germination in the high tunnels can be explained by the low soil temperatures, which were well below those required for germination and growth. Lettuces, which performed much better in the high tunnels, are adaptable to soil temperatures of 40-60°F.

Winter temperatures on the University of TN Organic Crops Unit for 2008-2009 were not significantly different from 2007-2008. Starting the above cool season crops in high tunnels in early late August or early September would probably increase chances of a successful fall harvest, or starting crops in mid February for early spring harvest. In the middle of winter, high tunnel production in East Tennessee is best geared towards leafy crops, which can withstand cooler soil temperatures. The low tunnel system using 10 gauge steel wire hoops and Agribon Ag-50 frost may offer a few weeks of season extension in the fall and spring, but should not be used for winter production, as temperatures often dip below the 24°F of protection offered. This low tunnel system is also sensitive to wind, as heavy winds caused the fabric to tear where it attached to the landscape staples. Kale is frost hardy to 20°F, and was the only crop in good condition in the low tunnels at the end of the experiment.