Crop Mix Experiences at North Central Research and Outreach Center

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A large number of crops will do well in high tunnel production. In particular, crops normally grown in your zone, plus many that are beyond your zone. For the market gardener that needs a large variety of crops to sell, high tunnel production may offer the opportunity to expand the season and grow a better quality product. Decisions about which crops to grow should be made the same way a grower would decide which crops to grow in normal field production. The use of high tunnels cannot replace previous ideas on crop mix, only enhance them. In Minnesota, the production of warm season crops offers the greatest chance for success with high tunnels. Therefore, the warm season crops should be the focus of high tunnel crop mix. Extending the early season with a cool season crop will only be successful if it does not conflict with the growing of the main season crop. If a cool season crop takes growing space and time away from the main season crop, the grower may not profit much. In choosing the crop mix, growers should select crops with similar temperature requirements to grow in the same high tunnel.

Several different crops have been evaluated in the high tunnels at NCROC. The comments that follow are observations on successes and failures.
Snap Bean
Cultivar: Jade (Siegers)
Seeded: 5/8/03 and 5/6/04
Spacing: Double rows 6 inches apart; 12-14 seeds per foot
Harvest: 7/14-7/24/03 and 7/13-7/26/04
Yields: 2003= 10.25 lbs/10 feet; 2004= 9.00 lbs/10 feet

Comments: Excellent quality, good yield, and slightly earlier maturity than with field production, but may not be that much better than what can be produced in the field.

Beets
Cultivars: Red Ace (Seedway) and Forono (Johnny's)
Seeded: 4/16/04
Spacing: Triple rows 4 inches apart; 14-18 seeds/foot
Harvest: Three=6/22/04 and 7/21/04-harvested the largest roots; 8/6/04-all remaining roots were harvested and marketed with the tops trimmed, but left on.
Yields: Red Ace=58.0 lbs marketable/10 feet.
Forono=51.4 lbs marketable/10 feet.

Comments: Excellent quality, excellent color, and very good uniformity

Broccoli
Cultivars: Six different cultivars were evaluated in 2003 and 2004.
Seeded: Transplants were seeded in greenhouse about 7/20 both years.
Transplants and direct seeding to the high tunnels was done about 8/20 both years.
Spacing: 8 inches apart in the row.

Harvest: November both seasons after frosts and cold weather damaged the plants.

Comments: It was thought that broccoli would be the perfect crop to transplant after carrots, beets, or green beans had been removed. The broccoli plants would establish and grow well in late summer, develop heads in late September, and mature nice bunches in October. Unfortunately that did not happen either season. Plant development in August was very slow, probably because it was too hot in the high tunnels for broccoli plant growth. The slow plant development delayed floret development, and cold weather in late October and November ended the season before mature heads could be harvested. None of the six cultivars evaluated were any better than the others. Early spring planting may react entirely differently and certainly would be worth evaluating.

Carrots
Cultivars: 2003-Mokum (Johnny's) and Ithaca (Johnny's)
2004-Mokum (Johnny's) and Kinko (Johnny's)

Seeded: 5/8/03 and 4/16/04

Spacing: Triple rows 4' apart; 16-18 seeds per foot

Harvest:
Mokum-7/21 and 8/6/03; 6/22 and 7/21/04
Ithasca-8/27/03
Kinko-6/22 and 7/21/04
All roots were harvested and marketed with tops trimmed but left on.

Yields:
Mokum-2003= 55 pounds per 10 feet; 2004= 26 pounds per 10 feet.
Ithasca-2003= 60 pounds per 10 feet.
Kinko-2004= 25 pounds per 10 feet.

Comments: The root color and uniformity were excellent. There were no doubles, splits, or cracked roots. Root quality and marketability were very good. There was no aster yellows evident in any of the roots. This factor is noteworthy because aster yellows is a serious problem in the Grand Rapids area in field grown carrots. These cultivars were selected because they all are short season maturing cultivars. It was felt that they could be grown and harvested, while still allowing enough time to successfully grow a second crop to maturity, perhaps broccoli. In 2003, it took 90 days for Mokum to mature the crop; in 2004, 96 days were required. Even with the earlier planting date of 4/16/04, the harvest date was too late to grow a second crop to maturity.

Cucumbers (Tables 1 and 2 give the results of the high tunnel trials.)
Cultivars: As listed. All were selected because they were gynoecious (all female), greenhouse forcing types.

Seeded: All were seeded into 4-inch peat pots sown 4 weeks before transplanting. Transplanted to the high tunnel 5/8/03 and 5/6/04.

Spacing: 18 inches apart in rows 4.2 feet apart.

Training: All trained to a single stem on a trellis.

Harvest: 2003=began 6/7/03. 2004=6/11/04-9/16/04; 33 harvests.

Yields: As shown in Tables 3 and 4.

Comments: Yields both years were very heavy, most over 3 pounds per square foot, making them the most productive vegetable of any grown in the high tunnels. The vine growth rate was heavy. The plants responded very well to pruning and training to the single stem training system and climbed easily up trellis string. Fruit began to mature about one month after transplanting, earlier than any other warm season crop. The fruit growth rate was fast and harvest needed to be done every day or, certainly, every other day to prevent the individual fruit from getting too big. Fruit is easy to harvest with this training system, as most of it is 3-4 feet off the ground within easy reach. Fruit set and development both seasons were good with few pollination problems. Depending upon the market, high tunnel production should probably be confined to greenhouse-forcing specialty types that will command a higher market price rather than the average slicing or pickling cucumber cultivar. The early market in June before field ripe~ cucumbers become available is probably the best market window. Plants continue to be productive into September. Cucumbers are very compatible in high tunnels with tomatoes and peppers.

Orient Express exhibited very heavy production (4.55 lbs per square foot). The fruit was very long and slender, sometimes becoming slightly twisted in shape. The fruit also had heavy spines, which were somewhat offensive even though they could be rubbed off. Sweet Slice was the earliest cultivar to mature. It also had the most misshapen fruit. Fruit was sometimes dumbbell shaped, or there was uneven development at the ends of the fruit. Diva is a very smooth spineless fruit that is shaped more like a regular cucumber. Sweet Success and Carmen are long greenhouse-forcing types, which had excellent shape, color and productivity. Both cultures probably also have the best marketability.
Table 1. 2003 Cucumber Production

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Source</th>
<th>1st Ripe</th>
<th>Early*</th>
<th>Ripe</th>
<th># Fruit/Plant</th>
<th>Lbs./Fruit</th>
<th>Lbs./Sq. Ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orient Express</td>
<td>BU</td>
<td>6/27</td>
<td>11.6</td>
<td>28.7</td>
<td>41.4</td>
<td>0.693</td>
<td>4.55</td>
</tr>
<tr>
<td>Diva</td>
<td>JS</td>
<td>6/30</td>
<td>7.3</td>
<td>22.0</td>
<td>31.4</td>
<td>0.700</td>
<td>3.49</td>
</tr>
<tr>
<td>Sweet Slice</td>
<td>ST</td>
<td>6/7</td>
<td>10.0</td>
<td>21.8</td>
<td>31.3</td>
<td>0.694</td>
<td>3.46</td>
</tr>
<tr>
<td>Carmen</td>
<td>ST</td>
<td>6/23</td>
<td>9.6</td>
<td>20.8</td>
<td>28.7</td>
<td>0.725</td>
<td>3.30</td>
</tr>
<tr>
<td>Sweet Success</td>
<td>BU</td>
<td>6/30</td>
<td>8.3</td>
<td>20.7</td>
<td>22.2</td>
<td>0.933</td>
<td>3.28</td>
</tr>
</tbody>
</table>

*Early Harvest Through 8/01

All of the cultivars evaluated in 2004 were greenhouse-forcing types except Niagara, which was a productive slicing type. Yields were not as heavy during the 2004 season because a more conscious effort was made to harvest fruit at a smaller size. The top yielding cultivar was Sweet Success, which was the poorest yielding cultivar in 2003. The cultivar Tasty Jade, an improved Orient Express, while not as productive, was of better quality than Orient Express. All cultivars in 2004 had very good shape with few misshapen or dumbbell fruit. Production in 2004 was terminated on September 16, due to a whitefly infestation that started on eggplants growing next to the cucumbers.

Table 2. 2004 Cucumber Production

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Source</th>
<th>1st Ripe</th>
<th>Early*</th>
<th>Ripe</th>
<th># Fruit/Plant</th>
<th>Lbs./Fruit</th>
<th>Lbs./Sq. Ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet Success</td>
<td>HM</td>
<td>6/11</td>
<td>12.9</td>
<td>22.9</td>
<td>31.2</td>
<td>0.735</td>
<td>3.63</td>
</tr>
<tr>
<td>Niagara</td>
<td>ST</td>
<td>6/29</td>
<td>14.0</td>
<td>20.3</td>
<td>33.0</td>
<td>0.614</td>
<td>3.22</td>
</tr>
<tr>
<td>Carmen</td>
<td>ST</td>
<td>6/17</td>
<td>11.9</td>
<td>19.8</td>
<td>28.2</td>
<td>0.703</td>
<td>3.14</td>
</tr>
<tr>
<td>Tyra</td>
<td>JS</td>
<td>6/25</td>
<td>9.7</td>
<td>16.8</td>
<td>25.4</td>
<td>0.663</td>
<td>2.67</td>
</tr>
<tr>
<td>Tasty Jade</td>
<td>JS</td>
<td>6/29</td>
<td>8.6</td>
<td>15.3</td>
<td>24.2</td>
<td>0.631</td>
<td>2.43</td>
</tr>
<tr>
<td>Cobra</td>
<td>ST</td>
<td>6/14</td>
<td>9.8</td>
<td>13.0</td>
<td>29.6</td>
<td>0.440</td>
<td>2.06</td>
</tr>
</tbody>
</table>

*Early Harvest 6/11/04 – 8/02/04

Eggplants

Cultivars: Fairy Tale-65 days maturity (All America Selection) and Neon-117 days maturity (Johnny's).

Seeded: Seeded in the greenhouse into 4-inch peat pots on 4/13/04. Transplanted to the high tunnel on 6/14/04.

Spacing: Double rows 4 inches apart; 18 inches apart in the row.

Harvest: Fairy Tale-Harvest began on 8/16/04. Seven harvests were conducted. Neon-No fruit matured.

Yield: Fairy Tale=14.9lbs from 10 feet of row. Fruit was small and averaged 0.15 pound each with 8.3 marketable fruit per plant.

Comments:
The cultivar Neon had very large plants and did not mature any fruit. The fruit of Fairy Tale
was small, tubular in shape, very uniform, and had nice burgundy color. Both cultivars seemed like a magnet to white flies. They were the plants on which white flies were first seen; and despite repeated insecticide applications, white fly infestation worsened until all of the eggplant plants were pulled and destroyed on 9/15/04.

**Snap Peas**

**Cultivar:** Super Sugar Snap-60 days- (Johnny's)

**Seeded:** 4/16/04

**Spacing:** Double rows were 6 inches apart; 12-14 seeds per foot.

**Trellising:** A five-foot high trellis wire was put between the rows for the plants to climb on.

**Harvest:** 11 harvest, each about 3 days apart. The first 6/14/04 (59 days)-final harvest was 7/19/04 (94 days).

**Yield:** 17.31bs per 10 feet; pod size was 6.6 pods per ounce.

**Comments:**
The plants were vigorous and very tall; easily reaching the top of the five foot tall trellis wire. The crop was easy to grow. No disease was evident. The harvest season was long with many pickings. The pods were uniform in size and had good quality, even late in the season when high tunnel temperatures were hot. This crop turned out to be a longer growing crop than was anticipated when it was selected as an early, cool season crop.

**Peppers, Sweet** *(Tables 3 and 4 give the results of the high tunnel trials.)*

**Cultivars**
As listed in Tables 3 and 4

**Seeded:** All cultivars were seeded into 4-inch peat pots in the greenhouse. 2003 - 3/13; 2004 - 2/13. All were transplanted to the high tunnels on 5/6/03 and 5/6/04.

**Spacing:** Double rows 4 inches apart; with individual plants 18 inches apart in the row.

**Harvest:** 2003 - harvest began on 7/17/03 and continued until late October. 2004-harvest began on 7/13/04 and continued until 11/5/04.

**Yields:** As shown in Tables 3 and 4.
Comments:
During both seasons, the pepper plants grew very large in the high tunnels. Early in 2003, the young plants were staked with small support stakes, since light breezes through the tunnel blew them over. With light support the plants stood up well both years. At various times, serious flower abortion and loss of potential fruit set occurred. While yields were average to good, this flower drop undoubtedly reduced total yields. About 25% of the crop both seasons matured by August 2.

2003 Season --Table 3
During the 2003 season, some of the pepper fruit had blossom end rot which affected fruit grade out. This problem was reduced in 2004 by the addition of calcium nitrate in the fertilizer program. The cultivar Socrates was the earliest to mature and had good fruit size, but its yield was average. Aristotle and Paladin had the best production, the best grade out and nicest quality fruit.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Source</th>
<th>1st Ripe</th>
<th>Early*</th>
<th>Ripe</th>
<th>% Good</th>
<th># Fruit/Plant</th>
<th>Lbs./Fruit</th>
<th>Lbs./Sq Ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aristotle</td>
<td>ST</td>
<td>7/24</td>
<td>1.1</td>
<td>4.1</td>
<td>84%</td>
<td>11.2</td>
<td>0.364</td>
<td>1.08</td>
</tr>
<tr>
<td>Paladin</td>
<td>ST</td>
<td>8/1</td>
<td>0.7</td>
<td>4.0</td>
<td>72%</td>
<td>11.7</td>
<td>0.342</td>
<td>1.05</td>
</tr>
<tr>
<td>Socrates</td>
<td>SE</td>
<td>7/17</td>
<td>1.2</td>
<td>3.1</td>
<td>61%</td>
<td>8.6</td>
<td>0.356</td>
<td>0.81</td>
</tr>
<tr>
<td>Red Knight</td>
<td>SE</td>
<td>7/28</td>
<td>0.4</td>
<td>1.8</td>
<td>53%</td>
<td>5.3</td>
<td>0.332</td>
<td>0.47</td>
</tr>
</tbody>
</table>

*Early Through 8/01

The cultivar Ace was the earliest to mature and had good productivity; but the fruit size was small, and the fruit was often sunken and misshapen. Vivaldi also was early and was the most productive cultivar. It had good size. Aristotle and Paladin had the largest fruit with the nicest shape, but their yields were intermediate. With no blossom end rot problems, the grade out on all cultivars was excellent in 2004 compared to 2003.
Table 4. 2004 Pepper Production

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Source</th>
<th>1st Ripe</th>
<th>Early*</th>
<th>Ripe</th>
<th>% Good</th>
<th># Fruit/Plant</th>
<th>Lbs./Fruit</th>
<th>Lbs./Sq. Ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vivaldi</td>
<td>SW</td>
<td>7/19</td>
<td>1.4</td>
<td>5.4</td>
<td>97%</td>
<td>16.8</td>
<td>0.324</td>
<td>1.42</td>
</tr>
<tr>
<td>Ace</td>
<td>JS</td>
<td>7/13</td>
<td>1.6</td>
<td>5.2</td>
<td>98%</td>
<td>22.3</td>
<td>0.232</td>
<td>1.37</td>
</tr>
<tr>
<td>Paladin</td>
<td>ST</td>
<td>7/23</td>
<td>1.0</td>
<td>3.4</td>
<td>94%</td>
<td>10.0</td>
<td>0.340</td>
<td>0.89</td>
</tr>
<tr>
<td>Brigadier</td>
<td>ST</td>
<td>7/21</td>
<td>1.2</td>
<td>3.4</td>
<td>97%</td>
<td>10.7</td>
<td>0.314</td>
<td>0.89</td>
</tr>
<tr>
<td>Aristotle</td>
<td>ST</td>
<td>7/26</td>
<td>0.8</td>
<td>3.0</td>
<td>94%</td>
<td>8.4</td>
<td>0.356</td>
<td>0.79</td>
</tr>
</tbody>
</table>

*Early Harvest 7/13/04 – 8/02/04

Radish

Cultivar: Crunchy Royal (Johnny's Seed)

Seeded: 4/16/04

Spacing: Triple rows 4 inches apart; 14-18 seeds per foot.

Harvest: Between 5/25 and 6/7/04, harvesting the largest roots each time.

Yield: 19.2 pounds per 10 feet.

Comments:
All were marketed with tops trimmed but left on. All of the roots were very uniform, had excellent color, and excellent quality. The roots showed no root maggot damage, which is usually a serious production problem in the field. The first roots were harvested between 39 and 50 days of planting. With an early April planting, this crop could be the early filler crop used before the main crop is grown. Late plantings may also work well.

Day Neutral Strawberries

Cultivars: Tribute and Everist

Planted: 5/14/03

Spacing: Double rows 1 foot apart; plants were 9 inches apart in the row.

Harvest: Began 8/18/03 and continued until 9/29/03.

Yield: See Table 5
Comments:
This planting was made to compare high tunnel production with field production. Several questions needed to be answered. One of the problems with production of day-neutral strawberries in the field is the long harvest season and the need of having to use many insecticide applications to control tarnished plant bug. Could high tunnel production reduce the damage from tarnished plant bug? The second question was could strawberry high tunnel production could be accomplished without introducing pollinating insects? Third, would the summer high tunnel environment be too hot for good dayneutral strawberry production to occur? Finally, would the day-neutral strawberry plants be able to survive the snow-less environment of the high tunnel in the winter?

Table 5. 2003 Day Neutral Strawberry Production. High Tunnel vs. Field Grown

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Location</th>
<th>Lbs./10 Ft</th>
<th>Lbs./Acre</th>
<th>Grams/Berry</th>
<th>Season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tribute</td>
<td>High Tunnel</td>
<td>4.3</td>
<td>4694</td>
<td>5.85</td>
<td>8/18 – 9.29</td>
</tr>
<tr>
<td></td>
<td>Field Grown</td>
<td>6.9</td>
<td>7514</td>
<td>7.38</td>
<td>8/18 – 10/9</td>
</tr>
<tr>
<td>Everist</td>
<td>High Tunnel</td>
<td>3.2</td>
<td>3452</td>
<td>6.43</td>
<td>8/18 – 9/29</td>
</tr>
<tr>
<td></td>
<td>Field Grown</td>
<td>4.3</td>
<td>4683</td>
<td>7.42</td>
<td>8/18 – 10/9</td>
</tr>
</tbody>
</table>

Table 5 shows the yields and fruit size that occurred during the 2003 fruiting season. Even in the field, yields were very average with small fruit size. The summer of 2003 was much hotter than average and was responsible for the poor yields that occurred. However, in the high tunnel yields were even worse than in the field. The high tunnel environment appeared to be too hot for day-neutral strawberry production. Pollination and fruit set did not seem to be a problem in the high tunnel nor was tarnished plant bug injury. The final question was answered in the spring of 2004, when the high tunnel plants did not survive the winter, despite heavy mulching. It appears that the type of high tunnels used at NCROC is too hot in the summer and too cold in the winter for day neutral strawberries to produce well.