**1. PROJECT NAME AND CONTACT INFORMATION**

**Exploring Alternative Growing Structures for Extending the Season and Improving the Quality of Organically Grown Cut Flowers (FNE04-503)**

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**2. GOALS**

Our goal was to evaluate the performance of several cut flower varieties in three kinds of tunnels (low tunnel, walk-in tunnel, and high tunnel – see the Appendix for tunnel descriptions) using three different covers (Covertan, Typar, and 6 mil greenhouse plastic) and two to three planting dates. We were seeking information that would help us match tunnel structures, covers and crops. Specifically, we were looking for the least expensive combination of structure and cover that would give us the highest quality cut flower crop.

**3. FARM PROFILE**

Windflower Farm is situated on 50 rolling acres in the Taconic Hills of southern Washington County, in New York State. It is owned and managed by Jan and Ted Blomgren, who grow 25 acres of organic vegetables, small fruits and cut flowers for 750 CSA shareholders in New York City.

**4. PARTICIPANTS**

Jan Blomgren was the coordinator of the project. Jan and Sue Kilpatrick, an employee of Windflower Farm during the 2004 growing season, did most of the plot work, including planning, planting, data collection and photography. Laura McDermott, a horticulture agent with Cornell Cooperative Extension (CCE) in Washington County, was a consultant on the project. Ted Blomgren wrote the mid-term and final reports.

**5. PROJECT ACTIVITIES**

In the spring of 2004, we planted ten cut flower varieties (stock, larkspur, snapdragon, godetia, lisianthus, Bells of Ireland, China aster, sunflower, Asiatic lily and delphinium) into raised beds on six-inch centers in each of four different tunnels (a low tunnel covered with Covertan, a walk-in tunnel covered with Typar, a walk-in tunnel covered with 6-mil greenhouse plastic, and a high tunnel covered with 6-mil greenhouse plastic). We utilized a total of three planting dates (April 10, April 25 and May 15), but not every variety was planted on every date. Thirty plants of each variety were planted in each tunnel on each date there was a planting. We produced the transplants in our greenhouse using 72-cell flats and a compost-based planting medium. Many of the treatments in the 2004 trial were replicated in 2005.

We gathered temperature and relative humidity data from three different tunnel structures and the out-of-doors. We did not collect rainfall data, but note that outside crops were never wanting for moisture during the wet 2004 season, and crops under plastic were irrigated once or twice each week, as needed. We gathered quantitative floral quality data (e.g., stem and inflorescence length, stem number per plant, and stem girth) on five cut flower varieties (including stock, godetia, larkspur, snapdragon, and bells of Ireland), out of a total of ten that were planted. Of the remaining five flowers in the trial (including China aster, Asiatic lily, sunflower, celosia and lisianthus), we made observations regarding their performance in the tunnels, but collected little quantitative information. In 2005, we limited ourselves to making observations.

**6. RESULTS**

**Tunnel Performance**

In May, the highest daytime temperatures were recorded inside the un-vented Typar-covered structure. The plastic-covered structures were ventilated, and remained cooler during the day. The plastic-covered walk-in tunnel warmed more quickly in the morning than the high tunnel, probably because of the walk-in tunnel’s smaller size. Nighttime lows were similar in all tunnel/cover combinations, and these were only about one degree F warmer than the outside. The Typar-covered tunnel was left open along its entire east side beginning in late May (the windward west side remained down the entire season), but it still remained several degrees warmer than the high tunnel during most June days, and was the quickest to become warm in the morning. Among the plastic-covered structures, highs were higher and lows lower in the walk-in tunnel compared with the high tunnel, again, probably because of the size (air volume) difference.

In June, nighttime lows were lowest under Typar, which were similar to outside temperatures. The sides of the Typar tunnel were opened very high at the end of June, which improved air flow and lowered daytime temperature highs. The plastic-covered walk-in tunnel was generally the hottest during July, although it remained about one degree F cooler than the high tunnel during the night. The temperature patterns established in July also prevailed during August, with the exception that daytime highs were often lower inside the tunnels than they were outside. Shading, in the case of Typar, and condensation build-up on the plastic-covered units probably explain this.

The plastic-covered tunnels were generally superior to Typar- and Covertan-covered tunnels in growing good flowers, regardless of the structure, and Typar and Covertan were, in turn, superior to the out-of-doors. These covers provided protection by degrees, with Covertan providing less day time warming, cooler night temperatures, and less wind protection, than Typar or plastic. Not all cut flowers were suited to the unique environment under a Typar-covered tunnel. The cut flowers we found most suitable to Typar were Asiatic lily, China aster, and Bells of Ireland. Cool-loving crops such as stock, larkspur, and snapdragon performed poorly under Typar.

Low tunnels easily become too hot when covered with plastic, and require too much labor to ventilate manually. The low tunnels covered with Covertan, which is breathable, were probably too cold in the early spring to give good results. Walk-in tunnels covered with plastic can become overheated if not managed effectively. High tunnels have provided the best horticultural results, mostly because of the material used to cover them, but also because of the size of the structure. The larger structure is less prone to wide temperature swings and is more forgiving of casual management. Walk-in tunnels have been nearly as good as high tunnels when covered with plastic. One of the key advantages of high tunnels over plastic-covered field tunnels is the capacity of the high tunnel to withstand significant snow loads.

In May, relative humidity was highest inside the plastic-covered units, intermediate in the out-of-doors, and, for reasons we don’t understand, lowest under Typar. In June, relative humidity was always highest in the high tunnel, and generally lowest under Typar (even when compared to outside RH). In July, the increased ventilation in the Typar unit increased the relative humidity under that cover. Relative humidity was lowest under the well-ventilated plastic-covered walk-in during July and August, which was similar to the outside.

**Cut Flower Performance**

**Stock (*Matthiola incana*)**

The growth and performance of stock was significantly affected by the kind of tunnel in which it was grown and the tunnel’s covering material (Table 1). The low tunnel covered in medium-weight Covertan produced the shortest stems and the shortest spikes. The high tunnel covered in 6-mil greenhouse plastic produced the longest and thickest stems and the longest spikes. Walk-in tunnels, regardless of covering, produced stems and spikes of intermediate length. The walk-in tunnel covered in plastic produced slightly longer stems than the one covered in Typar. Later plantings resulted in slightly shorter stems and slightly longer spikes regardless of the structure or cover.

***Table 1. Stock floral quality in four tunnel environments (measured in inches)***

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Structure | Cover | Planting  Date | Harvest  Date | Stem  Length | Spike  Length |
| Low Tunnel | Covertan | 4/25 | 6/19 | 12 | 8.0 |
| Walk-in Tunnel  Walk-in Tunnel  High Tunnel | Typar  Plastic  Plastic | 4/10  4/25  4/25  5/15  4/25  5/15 | 6/12  6/19  6/19  6/26  6/19  6/26 | 19  18  21  17  35  34 | 7.5  9.0  5.5  12.0  11.0  10.5 |

According Armitage (*Specialty Cut Flowers*, 1993, Varsity Press/Timber Press, Portland, OR), stock is a qualitative long-day plant, blooming more quickly as the length of daylight increases. As a rule, early spring plantings produce longer stems because more time is required before the plant is triggered to blossom. Later plantings produce shorter stems because they are triggered earlier in their lives to bloom. Our May 15th plantings required 14 fewer days from transplanting to harvesting than our April 25th plantings. An environment that would optimize growing conditions would be expected to produce longer stock stems during the relatively brief period of time the plant has to grow before making blossoms. Stock is a cold-hardy plant, experiencing little damage even as temperatures approach freezing, but growing more rapidly in warmer temperatures. Warm temperatures (above 65F) usually delay flowering, and cold temperatures (below 60F) promote it. The number of days to maturity was 7 days shorter in the high tunnel than in any other structure, regardless of planting date.

The high tunnel appeared to provide the best growing conditions: it was warm enough for optimal growth (long stems, numerous leaves) and cool enough to produce early blossoms. These results have been consistent over several seasons. In our experience, only spring plantings of stock have been viable for cut flower production. High tunnels and walk-ins have helped us extend the season by enabling us to plant earlier, but to realize these gains, we have learned that we must utilize the more expensive greenhouse plastic, and not Typar or lighter coverings such as mid-weight Covertan. In 2005, we successfully planted stock has early as April 1st. Earlier spring production of stock seems worthy of additional investigation.

**Larkspur (*Consolida* spp.)**

Larkspur performance was similar across all tunnels and covers (Table 2), and each treatment produced excellent results. Stem length, stem diameter and the number of stems per plant were each similar, regardless of tunnel or cover, although inflorescence length was greatest in the high tunnel (not a particularly positive development). Larkspur is very cold hardy and requires vernalization (cold treatment) for stem elongation and flower initiation. So, the cooler temperatures under the Covertan were not harmful to larkspur, and the warmer temperatures under the Typar and plastic were nevertheless cold enough for vernalization.

Because larkspur develops best under cool, long days, it is grown as a spring plant in the Northeast. Over the years, we have found that spring-grown larkspur planted unprotected in the field produces satisfactory results. If desired, we can achieve earliness in part of the harvest by placing floating row cover over a portion of the crop until the shoots begin to elongate. Not only is it unnecessary to use tunnels to produce high quality larkspur flowers, it probably doesn’t make financial sense. Tunnels are costly, and they should be used where they have the greatest impact. We eliminated larkspur from our high tunnels in 2005. In some locales (zone 6 and warmer), larkspur can be fall-planted and mulched, with the result that the overwintering plant is ready to resume growth when early spring conditions permit. In the Northeast, a tunnel might be used to create the conditions in which a fall-planted crop would succeed – an idea that may be worth further study. So far, we don’t think tunnels are warranted for larkspur production.

***Table 2. Larkspur floral quality in four tunnel environments (measured in inches)***

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Structure | Cover | Planting  Date | Harvest  Date | Stem  Length | Inflorescence  Length |
|  |  |  |  |  |  |
| Walk-in Tunnel  Walk-in Tunnel  High Tunnel | Typar  Plastic  Plastic | 4/25  4/25  4/25 | 6/19  6/19  6/19 | 48  42  48 | 7.0  7.0  12.0 |

**Snapdragon (*Antirrhinum majus*)**

Overall, the ‘Rocket’ snapdragons produced in each type of tunnel produced satisfactory results. The flower responded modestly to tunnel type and planting date (Table 3). The earlier planting produced stems that were 7” longer than the later planting in both Typar- and plastic-covered tunnels, but the later planting was ready for harvest in 14 fewer days. Stem length was greatest in the plastic-cover tunnels regardless of planting date, but the particularly long stems produced under the high tunnel were not as sturdy as those produced elsewhere, and snapdragon spike length was shortest in the high tunnel. The number of stems per plant varied from 2 in the low tunnel covered with Covertan (perhaps because of temperature extremes within the tunnel), to 5 in the Typar-covered walk-in, with the plastic-covered tunnels giving intermediate results. These numbers were slightly less than we expected; they do, however, exclude stems too short for straight bunches.

***Table 3. Snapdragon floral quality in four tunnel environments (measured in inches)***

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Structure | Cover | Planting  Date | Harvest  Date | Stem  Length | Spike  Length |
| Low Tunnel | Covertan | 5/15 | 6/26 | 28 | 10.0 |
| Walk-in Tunnel  Walk-in Tunnel  High Tunnel | Typar  Plastic  Plastic | 4/25  5/15  4/25  5/15  5/15 | 6/19  6/26  6/19  6/26  6/26 | 34  27  39  32  37 | 12.0  9.0  11.0  12.0  7.0 |

The garden variety snapdragons that we grow prefer cool weather and long days. Field production in the Northeast is best in the spring. Although snapdragon continues to produce well when temperatures in the field increase, stem and spike length generally decrease. The long-stemmed spring crop is excellent as a straight bunch; the less desirable summer crop is better when used in bouquets. The earlier, long-stemmed crop is more valuable, and tunnels are useful in extending earliness and enhancing quality. The less costly walk-in tunnels provided results comparable (or superior) to the high tunnel. For us, the walk-in is the better choice of structure because earlier planting dates that might be achieved in the high tunnel have not resulted in especially early harvests using the Group IV variety, Rocket - the long-day variety that is our favorite because it is inexpensive and highly branching.

Snapdragon is a quantitative long-day plant, but breeding has produced forcing varieties that bloom under a range of photoperiods. In 2005, we planted the Group III variety, Potomac, which was bred to bloom under the shorter days of spring and fall. The results were earlier harvests, which made better use of the high tunnel. The disadvantage in selecting a Group III variety is its lower yield of stems per plant, necessitating higher plant populations. The high tunnel is probably the better choice for the grower wanting the greater earliness that can be achieved here because it allows for far earlier planting dates than a walk-in tunnel that might collapse under a late winter or early spring snowfall. Because cool conditions slow plant development, further research is needed to determine just how early the cold hardy flower can be successfully planted in an unheated high tunnel.

**Godetia (*Godetia amoena*)**

Godetia stem length was greatest under the high tunnel (36”), but the stems were not as sturdy as those produced under the walk-in tunnels regardless of the cover (Table 4). The 24-27” stems achieved under the walk-in tunnel treatments were of high quality. Plants grown under the low tunnel produced very short stems, perhaps because of the stressful temperatures under the Covertan. Planting date did not impact stem length.

***Table 4. Godetia floral quality in four tunnel environments (measured in inches)***

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Structure | Cover | Planting  Date | Harvest  Date | Stem  Length |
|  |  |  |  |  |
| Walk-in Tunnel  Walk-in Tunnel  High Tunnel | Typar  Plastic  Plastic | 4/25  4/25  5/15  5/15 | 6/19  6/19  6/26  6/26 | 24  27  26  36 |

Godetia is a cool-weather plant, according to Armitage, and is intolerant of high temperatures. Day temperatures under 75 degrees and nights in the 50-55 degree range are best. It is not especially sensitive to light, although some cultivars blossom more quickly during long days. Taken together, these facts explain why godetia performs best in the spring. Summer temperatures are too warm for good floral development. We use Godetia in straight bunches when stem length is sufficient, and in mixed bouquets when it is shorter. We think that the less costly walk-in tunnel is a good choice for producing the longer stems for straight bunches; and that low tunnels and outdoor production are the better options for growing godetia to be used in bouquets.

We have concluded that the high tunnel is inappropriate for godetia, partly because the plant is so cold-hardy that it doesn’t benefit from the protection as much as other cultivars, and partly because it produces a stem that is too spindly in the warm high tunnel environment. Nevertheless, the high tunnel may be the best choice for the godetia grower wanting especially early production. Particular attention should be paid to spacing and pinching practices. To avoid weak stems in the high tunnel, we have learned that unpinched plants should be spaced about 4” apart, and that pinched plants should be given about 24”. In 2005, the plastic-covered walk-in tunnel again produced good yields of 24-30” godetia.

**Lisianthus (*Eustoma grandiflorum*)**

Lisianthus performance was a function of the tunnel structure in which it was grown (data not shown). It performed best in the high tunnel, giving excellent stem length (>24”), a high proportion of marketable stems, and a good second harvest. Lisianthus performance in the walk-in tunnels was also very good (18-24”), but losses to *Fusarium* in the Typar-covered walk-in were high. The flower fared poorly in the Covertan-covered low-tunnel, producing short stems on weak plants, and little of marketable quality. The number of marketable stems per plant (about 3) was similar across the remaining treatments. In 2005, lisianthus performed well in the plastic-covered walk-in tunnel and in the high tunnel. A later planting of lisianthus in a low tunnel also performed well, but grew on shorter stems and failed to produce a fall crop before the arrival of freezing temperatures.

Lisianthus performs best at greenhouse temperatures below 70 degrees. It blooms slightly faster under long days, but will still bloom under short days. Armitage claims that its chief drawback is the long time (from 5-7 months) required between planting and harvesting. In our experience, the time between transplanting the 2-3 month-old plugs in the tunnel and harvesting the cut flowers is about 3 months, which is an acceptable period of time to tie up greenhouse space for production of a very high quality crop. Late June blooms require a mid-January sowing date. Because we regard lisianthus as one of the best annual cut flowers we grow, we are willing to give it premium space. Although we’ve had satisfactory results from low tunnels and unprotected field plantings, we have only been able to harvest a summer crop from them. By planting lisianthus under a tunnel, the season is extended long enough to get a second harvest in the fall. We have concluded that the high tunnel is a good choice for very early lisianthus production, and that the plastic-covered walk-in tunnel is a good choice for production of a second succession of lisianthus. If a third succession is desired, a low tunnel would likely be the best choice, producing a late summer crop, but not one in the fall. Because rainfall damages lisianthus blossoms, some kind of cover is usually beneficial any time of year.

**Bells of Ireland (*Moluccella laevis*)**

Bells of Ireland performed very well under the tunnels. Bells of Ireland stem length was longest in the high tunnel, but still in excess of 32” in the walk-in tunnels (Table 5). The numbers of stems per plant and inflorescence lengths were similar across all treatments except the low tunnel. The low tunnel produced shorter plants because, we think, the Covertan provided only modest protection against the cold temperature early in the season. It usually performs best when planted early. High tunnels are the best choice for crops planted while the risk of snowfall is high, and walk-in tunnels, because they are less expensive, are the best choice for later plantings. Once the weather has warmed, tunnels are no longer needed for Bells of Ireland production, and direct-seeding in the field is probably the most cost-effective means of producing the crop. Bells of Ireland suffers in windy locations, however, and appears to produce shorter stems as the season warms. Better summer results might be achieved through use of covers that offer protection from the wind and a degree of shade, but field evaluations would be needed for verification.

***Table 5. Bells of Ireland floral quality in four tunnel environments (measured in inches)***

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Structure | Cover | Planting  Date | Harvest  Date | Stem  Length | Inflorescence  Length |
|  |  |  |  |  |  |
| Walk-in Tunnel  Walk-in Tunnel  High Tunnel | Typar  Plastic  Plastic | 4/25  4/25  4/25 | 6/26  6/26  6/26 | 32  34  45 | 12.0  12.0  12.0 |

**China Aster (*Callistephus chinensis*)**

In this trial, China aster stem length was dependent on the tunnel structure in which it was grown (data not shown), but all tunnels produced satisfactory results. China aster performed well in the high tunnel and the plastic-covered walk-in tunnel, with stem lengths in excess of 36”. Stem length in the Typar-covered walk-in was greater than 24”, and in the Covertan-covered low tunnel it was 24”. Field-grown China aster stems measured a disappointing 18”. Stem and blossom numbers were similar across treatments. This was the cut flower that we thought Typar would benefit most. We were seeking a breathable cover that excluded insects on the one hand, but that allowed enough ventilation for good plant growth on the other hand. In 2005, we were pleased with the performance of Typar.

As a field-grown cut flower, China aster performs best during the mid-summer in the Northeast. China aster flowers best when a period of long days is followed by a period of short days, or at the approach of mid-summer in the Northeast. Because plants grown under the long-day conditions of late spring flower slowly and on very long stems, and fall-grown plants sometimes fail to elongate altogether, the flower does not lend itself to a great deal of season extension. Using earlier planting dates, we have not been able to produce earlier crops in the high tunnel. The flower was not given the environmental signals to initiate flowering until the day length began shorten. Nevertheless, walk-in tunnels have demonstrated their usefulness in modestly extending the season and, more importantly, in enhancing China aster quality. An additional benefit of walk-in tunnel production is that the crop is isolated from the leafhoppers that transmit the aster yellows virus. We have concluded that the walk-in is more appropriate than the high tunnel for China aster production for simple economic reasons: the less expensive structure gives comparable results. A tall version of the low tunnel – with hoops tall enough to allow the cover to remain in place until harvest – provided excellent results in 2005.

**Sunflower (*Helianthus annuus*)**

In this trial, sunflowers grew too tall in most tunnel structures, regardless of the cover, and produced over-sized stems and undesirable flowers. Sunflowers grown under the Covertan-covered low tunnel performed well, although stem size was still unusually large. The low tunnel cover was removed when the plant reached the top of the hoop, and the plant went on to produce high quality blossoms. Sunflower production was best when grown in an uncovered environment. These results conflicted with past experience, when we had successfully grown sunflowers in plastic-covered walk-in tunnels. Our problems may have had to do with excessive compost rates or poor variety selection. When repeated in 2005, using a more compact variety (‘Sunbright’) and a tighter spacing, the walk-in tunnel produced a better crop.

Although many sunflowers are affected by photoperiod, the cutting types are mostly day-neutral. Temperature has a far greater impact on sunflower growth and development, with temperatures between 65 and 75 degrees being optimal, and those below 50 degrees stopping growth altogether. Sunflowers are good prospects for tunnel production because they are very responsive to the warmer environment and they give marketplace rewards. We transplant our first succession of sunflowers under walk-in tunnels covered with plastic, our second succession of sunflowers under low tunnels, and our third sunflowers in the open field. Our remaining sunflowers are direct-seeded. Sunflowers grown under walk-ins are two to three weeks earlier than their field-grown counterparts. Tall plant growth can be a problem in the tunnel, but this can be addressed with use of high plant populations and selection of shorter varieties.

**Asiatic Lily (*Lilium hybrids*)**

Asiatic lily performed well in the high tunnel and in the walk-in tunnels, regardless of the cover, with stems about 30” long, and good blossom quality (data not shown). Stems were 6 and 12” shorter in the low tunnel and in the field, respectively. The lilies in the tunnels performed better than those in the field because temperatures in the tunnels during the cool trial season were better suited to good plant growth. Lilies require cold temperatures to initiate flowering, which is usually achieved during cold storage of the bulb, but temperatures ranging from 55 to 65 degrees result in the fastest growth and development of the flower – a range more consistent with plastic-covered tunnels. The high light of early spring and summer is adequate for good flowering. The primary drawback to Asiatic lily production in the tunnel is the time required from planting to harvesting – about 90 days.

**Celosia (*Celosia argentea*)**

Celosia was not part of the original trial, but it is a cut flower we like very much, and one we’ve experimented with in a variety of tunnels. It is a qualitative short day plant, meaning that, although it will flower under any day length, it will flower fastest as the days begin to shorten in mid-summer. Celosia also grows best during the warm temperatures of summer. Its performance is similar to that of China aster. Especially early tunnel plantings have not proven worthwhile - stems grow too long and wispy if planted in April, for instance. Later plantings produce better, shorter, more robust stems. Tunnels are still useful for achieving earliness. High tunnels or plastic-covered walk-in tunnels are best for early May-planted crops. Because we don’t plant celosia until late May, we have concluded that low tunnels are best for establishing our crop. They provide a good, protected start to the plant, and by the time the cover must be removed to accommodate the elongating stems, warm outdoor temperatures have arrived. The taller of the low tunnels (those made using hard poly bows) are not necessary for celosia because insects are not particularly troublesome in mid-summer and it is safe to remove the cover.

**7. CONDITIONS**

A significant late-May hailstorm, accompanied by heavy rainfall, had an adverse impact on the trial. Some treatments experienced flooding and had to be abandoned, and wet conditions prevented us from erecting a multi-bay structure that would have been a fourth tunnel treatment. Delphinium was ruined in several plots and the flower was eliminated from the trial. Overall, the season was wetter and cooler than usual. Nevertheless much of the trial was successful and we were able to gather a good deal of data. The 2005 season was less eventful. We gathered valuable information on how several cut flower varieties performed in a variety of structures, and under a variety of covers. A warmer season might have benefited the Covertan-covered low tunnel, but this experience pointed out that the plastic-covered units do a better job of reducing weather-related risk.

**8. ECONOMICS**

The question we set out to answer was essentially an economic one. We wanted to know if the less expensive structures we’d recently begun working with – walk-in tunnels – would produce flowers as well as the more expensive high tunnel structures we’d already been using. And, for the most part, the answer was “yes.” As a result of better matching the tunnel and cover to the crop, we have been able to produce high quality cut flowers at a significantly lower cost. Cut flower production in tunnels is vastly superior to cut flower production in the field, so it makes sense to increase the amount of space we have under tunnels. Walk-in tunnels cost a fraction of what high tunnels cost on a square-foot basis, and low tunnels, in turn, cost just a fraction of what walk-ins cost. For every square-foot of high tunnel space we might purchase, for instance, we could purchase seven square-feet of walk-in tunnel space.

**9. ASSESSMENT**

The project helped us appreciate that low-cost structures are indeed capable of producing the same kinds of results that high-cost structures produce. In the future, we will continue our search for cost-effective tunnels for growing high quality cut flowers. We will also continue our work to identify cut flowers that perform well on our farm, making sure to match them with the structures, planting dates and cultural practices that best suit them.

**10. ADOPTION**

The information we gathered in this trial has been highly valuable to us. We have learned to use our high tunnels mostly to grow stock, early lisianthus and snapdragons, and one or two other high-value crops, because they benefit most from the high tunnel structure. We use walk-in tunnels for almost all of our other cut flowers because the walk-in has performed just as well as the high tunnel, at a fraction of the cost. In fact, as we’ve increased the amount of land we have under cover, it has mostly been through construction of more walk-in tunnels. We have not used Typar very extensively since the trial, but remain convinced that it is a good option for certain crops, especially warm-tolerant flowers that are susceptible to insect infestation. We have increased our use of low tunnels, especially for production of “second early” cut flowers. For later plantings, low tunnels provide excellent results at a fraction of the cost of walk-in tunnels.

**11. OUTREACH**

We have created a PowerPoint presentation that provides an overview of season extension for cut flowers using a variety of tunnels. The PowerPoint was presented at the NOFA-NY conference in 2005, the New England Vegetable & Berry Conference in 2005, the New England Greenhouse Conference in 2006, the Upper Midwest Organic Farming Conference in 2007, a North Country Extension high tunnel conference in 2008, and the Saratoga Springs Farmer-to-Farmer Conference on high tunnels in 2008. A newsletter article summarizing our findings was written for the Cornell Small Farms Gazette and the Cornell Agriculture and Life Sciences News. And in June of 2005, growers and agriculture professionals were invited to an open house at our farm where they could see the tunnels themselves.

**12. REPORT SUMMARY**

Our goal was to evaluate the performance of ten cut flower varieties in three kinds of tunnels using three different covers and two to three planting dates. We were seeking information that would help us match tunnel structures and covers in a way that would give us the highest quality cut flower crop.

Stock and lisianthus both performed better in the high tunnel than in any other structure. Most other cut flowers performed very well in the high tunnel, too, but they performed just as well in the less expensive structures. Even “second early” plantings of stock and lisianthus have performed just as well in the walk-in tunnel.

Unlike high tunnels, walk-in tunnels are not snow-bearing structures. In this area, they can only be used from late April through late November. The chief advantage of a walk-in tunnel is that it costs much less than a high tunnel. Temperatures within walk-in tunnels are fairly similar to those inside high tunnels, although temperature highs are slightly higher and lows are slightly lower in the walk-ins. Using breathable Typar to cover a walk-in tunnel creates a warmer (when un-vented) and less humid tunnel environment. With respect to most cut flowers, the walk-in tunnel covered with greenhouse plastic performed similarly to the high tunnel. Snapdragon, for example, performed very well in the walk-in tunnel when covered with greenhouse film. Bells of Ireland, Godetia, Asiatic lily, and China aster each performed very well in walk-in tunnels, regardless of the covering. The breathable cover is useful for cut flower production because it excludes insects, but it can create an environment that is too hot if not vented.

Low tunnels can be used from about May 1st through late November in this area. They are the least expensive structures for extending the season. Temperatures inside low tunnels covered with breathable materials are often cooler than those inside high tunnels. When plastics are used as low tunnel coverings, temperatures can become excessively hot. Even breathable fabrics can produce an environment that is too hot. As a rule, high tunnels and walk-in tunnels have produced better early-season cut flowers than low tunnels. Low tunnels remain a good choice for second early crops because they produce good later crops, and they do it very economically.

**APPENDIX**

**The Tunnels at Windflower Farm**

We use a number of structures to extend the cut flower season, including low tunnels, walk-in tunnels, and high tunnels. Each has unique strengths and weakness, and each has a different impact on the cost of production. We are seeking information that will help us identify the most economical structure for use in producing a variety of high quality cut flowers.

**Low tunnels** are used widely in commercial vegetable production to extend the season of warm-loving vegetables. They work primarily by increasing daytime temperatures. Low tunnels provide some wind protection and a few degrees of frost protection. They are made by placing #10 wire hoops over the row at intervals of 4-6’ in order to suspend narrow row covers or slitted or perforated clear plastic over the young plants. A problem that cut flower farmers face is that flower stems sometimes outgrow the low tunnel (necessitating row cover removal) before problems with wind and cold temperatures have abated. We have increased the height of our tunnels by switching from wire hoops to one-inch hard poly pipes cut into 9-foot lengths. In the case of China aster, for example, the low tunnel is tall enough that the cover need not be removed until harvest time, even if stems reach 36”. Low tunnels cost less than $.10/ft2, depending on the type of cover selected, making them the least expensive structure with which to extend the season. They provide modest season extension at a modest cost. Low tunnels are not suited to crop production in early spring or late fall when snowfall would damage the structure. The cost of growing crops in low tunnels includes annual construction and demolition of the tunnel, and disposal costs.

**High tunnels** are essentially greenhouses without heaters or automated ventilation. They are covered with standard greenhouse plastic. Ventilation is accomplished using rollup sides. Some growers use portable heating systems to prevent freezing injury to crops. A wide range of sizes is available. Inside the high tunnel, raised beds and wide row covers are frequently used. High tunnels produce the earliest flowers of all the tunnels we use, and some growers use them to produce their most valuable varieties. Although not nearly as expensive as heated greenhouses, the cost of these units can be prohibitive. To reduce unit costs, growers often produce two successions of flowers each year from each bed in a tunnel. High tunnels cost about $.3.45/ft2, or more, depending on choices related to site modification, utilities, labor, materials, and details. High tunnels are designed to withstand snow, hence, they can be used to extend the season much longer than walk-in tunnels. Multi-year greenhouse film is used to cover high tunnels, and the costs related to new cover installation every four years, along with the removal and disposal of the old cover, is part of the operating cost. Given the high cost, the primary reason to choose a high tunnel over a plastic-covered walk-in tunnel is that the high tunnel can be planted earlier, when there is still a chance of heavy snowfall.

**Walk-In Tunnel** size is variable. They range from 8' to 18' in width and cover from one to several beds. Their length may be from 20' to 300' or more, depending on the length of beds they are intended to cover and limits to the sizes of available covers. The flexible tunnel length enables a grower to construct a walk-in tunnel virtually anywhere on the farm because it can be sized to fit into a farm’s existing bed system. The tunnels are tall enough to walk in and are accessed by ducking under the sides anywhere along their length (hence their name).

Bows for walk-in tunnels may be made from PVC, electrical conduit, or galvanized steel hoops. To erect the tunnel, the bows are either slipped over ground stakes made of rebar or tubular steel, or the bows are set directly into the ground about a foot deep. Bows are spaced six to ten feet apart, depending on the site’s wind exposure. It is best not to construct the tunnel broadside to the wind, but if that is unavoidable, the tunnel will serve as an effective windbreak for crops planted on its lea side.

A 1/4'' rope tied from hoop to hoop is used to form a ridge purlin. The purlin is attached to heavy-duty ground stakes at both gable ends. The structure is quite “loose” when uncovered; much of the tunnel’s structural integrity comes from the cover and the way it is secured to the ground. Walk-in tunnels may be covered with greenhouse plastics, heavy spun-bonded fabrics such as Typar, or shade cloth. The cover should be matched to the intended use of the structure.

The covering is held fast by 1/4'' ropes that are drawn over the top of the structure (Canastoga wagon-style) and are secured to stakes or earth anchors in the ground. These ropes give the structure its segmented, caterpillar-like appearance. The edges of the plastic are left loose, but the covering should be sized so that there are at least two feet of extra material on each side. In particularly windy locations, the covering may be additionally secured by placing rocks or small sand bags on the edges of the plastic. At the gable ends, the plastic is bunched together using rope, and the rope is tied to a secure stake. The tunnel’s dimensions should be configured to fit commonly available greenhouse films or floating row covers. While they have many advantages, starting with their cost, walk-in tunnels are really three-season structures. The wide bow spacing that keeps them cost-effective greatly reduces their snow-load capacity, so the covering should be removed before winter. However, walk-in tunnels with a bow-to-bow spacing of 4' and a width of 10' have reliably withstood snow.

Walk-in tunnels must be ventilated manually to avoid excessive temperatures. During the coldest periods of the year, sections of the sides (the cover) are propped up with short “Y” shaped props or branches cut for the purpose. When temperatures warm, the sides may be rolled up along the entire length of the tunnel. Clamps or tall “Y” props can help hold the rolled up plastic in place. The sides must be rolled down when high winds threaten. These tunnels are highly portable. They may be erected and dismantled relatively quickly. For example, we built two 200' long units over three-bed sections of lettuces with a co-worker over the course of a morning.

One way to reduce the annual costs of construction and dismantling is to leave the caterpillar tunnel in place from year to year, and to develop a list of tunnel crops around which a crop rotation plan might be developed. Walk-ins are highly adaptable structures. They may be built over existing crops, or over bare ground for a later planting. They may be built in the fall, left uncovered during the winter, and then covered in the spring for an early planting.

Walk-in tunnels are more expensive than low tunnels, but provide greater season extension and generally produce superior flowers. Although more tolerant of snowfall than a low tunnel, walk-ins would also be ruined by heavy snow loads. The cost of growing crops in these structures includes the cost of “skinning” the structure in the spring, and removing the plastic in the fall. New greenhouse film is purchased, and old plastic is disposed of, every 4-6 years.

*Submitted by Ted Blomgren, January 25, 2009*