Ensuring success
Protected horticulture: productivity based on levels of technology

By Paula Costa and Gene Giacomelli*
prr@u.arizona.edu,
giacomel@ag.arizona.edu

Mexico is bursting with recently developed greenhouse vegetable production facilities, estimated at 92,000 metric tons and worth $225 million in 2002. The total estimated area of protected horticulture in Mexico is approximately 2,208 hectares with 539 ha planned for construction (insect screen only operations not included). Currently, tomato production (including beef steak, cherry and cluster/ToV) accounts for 70% of all greenhouse vegetable crops in Mexico. These statistics are from Mario Steta, Agros, S.A. de C.V., presented at the Arizona Greenhouse Short Course (2005). The greenhouse industry is growing at such a fast rate that accurate and updated statistics are difficult to find, but unofficial statistics estimate a growth rate of 10 – 15 % a year (Steta, 2005).

Although the potential of the Mexican greenhouse vegetable industry is tremendous, so is the potential for failure. The fast-pace development of the greenhouse industry –or of any industry for that matter– makes it ripe for mistaken investments. Poorly targeted greenhouse production technology can result in economic disasters, in part because of unreasonable expectations of quality and yield. Problems that generally plague fast-developing industries are unreliable and/or inconsistent supply of production resources, including insufficiently trained management and hand labor, inadequate financing, and misplaced technology.

We believe that an understanding of the potential expectation of productivity based on the level of technology chosen will direct greenhouse investors to make more informed business decisions, and therefore improve potential for success.

Selecting technology
The main factors for selecting technology for greenhouse production are cultivar requirements, climate characteristics, available capital for the technology investment, and labor expertise. All of this should be factored into the business plan, as well as considerations regarding the target market, seasonal market trends and price fluctuations.
Shifting from open field to greenhouse production results in a new set of challenges and production requirements, which means training workers and developing the grower’s technical experience of a crop in a controlled environment are top priorities. The grower must make sure the technological package he/she selects includes the desired level of technical support, from the initial project design to daily operations. This latter statement cannot be stressed enough. Many greenhouse failures are due to lack of technical support.

The greenhouse tomato industry in Mexico today is characterized by a wide variety of technology levels within several types of climatic environments. Important climate factors are the intensity and yearly distribution of solar radiation, air temperature and relative humidity. The best locations for year-round greenhouse production fall within the high desert regions of Northern Mexico (North Sonora and Chihuahua), and the high regions of Central Mexico, while coastal regions typically have a shorter season due to either excessively hot summers (Sea of Cortez) or cold winter (BCN, BCS). However, each climate has environmental potential and limitations that can be overcome by adequate choice of technology.

The technology level of a greenhouse is the combination of systems that, when incorporated within the greenhouse modifies the plant canopy and root environment. These systems range from simple to complex. For the purposes of this article, the definition provided by Pardossi et al., 2004, is quite useful. The authors define three greenhouse technology levels that enable plants to produce an economical yield, including: 1) low technology, with minimal environmental modification to sufficiently modify the microenvironment; 2) high technology, with maximum environmental modification, creating a microenvironment for optimal plant growth and yield, and 3) medium technology, with various combinations of the previous two. Components of these technology levels for tomato production are summarized in Table 1.

Following is a closer look at the characteristics of low, high and medium tech greenhouses, including advantages and disadvantages with consideration given to geographic location.

**Low technology greenhouse**

Any location in which adequate climate can be extended to three seasons beyond spring and fall is potentially appropriate for low technology greenhouses (see Table 1 for characteristics). Typically these are simple steel frame structures with PE glazing, passive cooling and no heating. Low technology greenhouses typically do not have automation. Greenhouse environmental conditions are greatly dependent on outside climate, and therefore yields cannot be optimized.

In Mexico, these types of greenhouses can be found in the coastal regions, including BCN, BCS and Sea of Cortez. In Southern Sonora and Sinaloa, warm winters allow growers to extend crop production through the winter (Fall-Winter-Spring), while in BCN (as well as high central Mexico) cool summers allow production through the summer (Spring-
Summer-Fall). However, without active cooling/heating, low technology greenhouses do not allow for year-round production, and fruit quality will be affected.

Protection from outside climate conditions offers warmer daylight temperatures, wind protection, and some insect exclusion compared to open field. Typical environmental conditions of a low technology greenhouse are:
1) large day-to-night air temperature fluctuations, with low temperatures at night and high temperatures during daytime,
2) limited or excessive ventilation, due to lack of proper control systems,
3) CO2 depletion, causing a reduction in crop growth, yield and fruit quality.

Combined, these factors have a negative impact on the plant growth and fruit development due to reduced transpiration, leaf cooling, water/nutrient uptake, and photosynthetic rates. This often results in increased blossom end rot (BER), fruit cracking, fruit russetting, and plant diseases, as well as an inability to control the vegetative/reproductive plant balance. Technology from Israel, Spain and Mexico is commonly used.

**High technology greenhouse**

The modified Dutch greenhouse has been considered the standard for high technology (Table 1). It typically includes a glass-covered, aluminum structure, with plant-based environmental controls that optimize plant conditions for optimal growth, maximum productivity and fruit quality. However this now includes some French and Spanish polyethylene greenhouses with Dutch climate controls.

Automated plant-based environmental controls that carefully monitor and control the environment for optimal plant growth may provide maximum productivity and fruit quality, year-round. The environment is optimized both at the plant canopy (air temperature and relative humidity), and at the root level by root zone heating, watering and nutrition control. Air temperature control is maintained by heating systems and forced ventilation with evaporative cooling (pad and fan or high pressure fog systems). Automated fertigation and shading according to irradiance levels and continuous CO2 enrichment results in almost complete independence from outside conditions.

Significant reduction in production costs and minimal environmental impact can be achieved by adopting a closed irrigation re-circulation system in which water and nutrient resources are recycled and reused. Recirculation systems must include water/nutrient solution sterilization equipment. Shortage of good quality water resources and increased awareness about environmental impact issues are strong reasons to adopt these water-efficient systems. Integrated pest management (IPM) procedures for pesticide-free products are common practice at this level of technology.

Continuous year-round production of the highest quality fruit sold at the premium prices is the best way to offset the high initial investment costs, which can reach 200 $/m2 (Table 1). Labor costs increase for high technology greenhouses, due to the need for highly-trained hand labor and experienced growers/crop managers. However, proper design and layout of...
the greenhouse optimizes space utilization to gain increased production per unit area, energy savings, and more effectively use of labor. In addition, the work is year-round, providing permanent career jobs and minimizing labor turnover.

Medium technology greenhouse
Many regions of Mexico, such as Jalisco, Sonora, Baja California North as well as Central Mexico, have climate conditions where an intermediate level of crop protection is sufficient. Medium technology greenhouse includes systems that are a compromise between the low and the high technology greenhouse (Table1). Technology from Spain, Israel, France, U.S. and Canada are common in these regions. Designs include either passive ventilation systems, with roof and/or side vent openings, or active environmental control systems with pad and fan cooling and heating systems. Basic computer control and automated shade curtains are sometimes included for improved climate conditions. Crop production for control of the plant root zone includes several substrate options that range from amended soil to soilless substrates such as coir, perlite, and rockwool. Computerized fertigation is common with the advantage of consistent timing and improved watering uniformity.

Conclusions
As the Mexican greenhouse tomato industry continues its accelerated growth, careful selection of technology for a given climate and market situation is crucial. Technology should be selected at an appropriate level, meaning that the highest and most complex technology level may not be desired, if a more simplified technology will provide the required productivity to meet the market demands and expected revenues. Regardless of the technological level, it is important to keep in mind that the greenhouse industry is just another business enterprise. It must follow the market rules regarding supply and demand. Therefore, level and timing of production, and fruit quality play a significant role in defining the target market and successfully winning it. Thus each new operation should be based on a marketing plan that includes in-depth knowledge of the target market, production cost, expected yields and fruit quality. Finally the importance of continuous access to technical support along with training/educational programs with high performance standards can never be overemphasized.

The authors: P. Costa is a PhD Candidate at the University of Arizona in Tucson, Arizona. and G. Giacomelli is Professor and Director of the Controlled Environment Agriculture Center (CEAC), at the University of Arizona in Tucson, Arizona. CEAC Paper Number M-125933-??-05

Sources cited:
All references cited are approximated values from unofficial sources.

Table 1. Components of technological levels for greenhouse CEA, including respective yield and investment costs.

<table>
<thead>
<tr>
<th>Environment</th>
<th>Structure &amp; Glazing</th>
<th>Canopy</th>
<th>Root</th>
<th>Culture method</th>
<th>Expected yield kg/m²/yr</th>
<th>Investment Cost a $/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Wooden or Steel frame Single layer PE film</td>
<td>Passive cooling (roof and side wall vents) no heating</td>
<td>Soil or tezontle/sand Drip irrigation with manual control</td>
<td>Med-high wire</td>
<td>10-20</td>
<td>25-30</td>
</tr>
<tr>
<td>Medium</td>
<td>Steel frame Double PE film or rigid plastic</td>
<td>Passive/Active cooling (vents +pad /fan) with or without air heating and basic level of computer control</td>
<td>Soil or soiless substrate Drip irrigation with some control</td>
<td>High wire culture Longer season Usually computerized fertigation</td>
<td>20-50</td>
<td>30-100</td>
</tr>
<tr>
<td>High</td>
<td>Steel or Aluminum frame Glass,</td>
<td>Forced ventilation+ evaporative cooling + hot water pipe heating + CO₂</td>
<td>Soilless substrate Rockwool, coir, other</td>
<td>High wire culture Fully computerized</td>
<td>50 - 75 b</td>
<td>100-200+</td>
</tr>
<tr>
<td>polyethylene or Polycarbonate</td>
<td>enrichment + shading according to light intensity + energy blanket</td>
<td>Drip irrigation with full automated control (EC control according to light intensity)</td>
<td>fertigation Recirculation Hydroponics</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*source: Pardossi et al., 2004*

*with knowledge of artificial lighting and intercropping these results can be as high as 100 kg/m² (Jensen, 2004)*