Bright Future in High Light - Greenhouse Vegetable Production in the Sonoran Desert

by Merle Jensen
University of Arizona, Tucson

For nearly forty years the University of Arizona has done extensive research in greenhouse vegetable production. It was here the term "Controlled Environment Agriculture" was first coined to describe the ultimate in environment control; maintaining control at both the aerial and root levels. Research at the University took place in totally enclosed structures that permitted control of air and root temperatures, humidity, atmospheric gas composition, light, water, growing media, and plant nutrition.

While hydroponics and controlled environment agriculture (CEA) are not synonymous, CEA usually accompanies hydroponics. Their potentials and problems are inextricable. Such systems are high technology and capital intensive. They are possibly the most intensive methods of crop production in today's agricultural industry.

In the early 1970's, hydroponic/soilless culture systems became popular in the United States, especially Arizona. In part this occurred through research at the University of Arizona and through private investment. In private practice, failures far outnumbered the successes, due to management inexperience or lack of scientific and engineering support. Unfortunately, hydroponics is an inherently attractive, often over simplified technology, which is far easier to promote than to sustain.

However, in recent years, extensive research and development programs both in the United States and Europe have vastly improved hydroponic/soilless culture systems. Today, these new technologies, especially those from Holland, are successfully being transferred to the desert southwestern region of the United States and Mexico. Growers appear to be much more critical in regard to site selection, structures, the growing system, pest control, and markets.

Prior to 1970, the greenhouse vegetable industry was located near the high population centers, mainly in the states of Ohio, Michigan, and Massachusetts. All commercial production was in soil.

In 1965, Ohio was the major greenhouse vegetable region in the United States, with over 600 acres. After 1970, with the rapid rise in energy cost to heat greenhouses along with the construction of superhighways to transport fresh produce from southern regions, Ohio became an importer of tomatoes. The greenhouse vegetable industry in all the above-mentioned states has essentially collapsed and today is insignificant.

With the superhighways in America, the energy to transport fresh vegetables from the southern region of the United States and from Mexico is less than that energy to heat a greenhouse. For example, in conventional greenhouses in Ohio, it takes nearly 40,000
kcal of energy to grow one kilogram (2.2 lbs.) of tomatoes versus only 4,000 kcal for a like amount grown in an open field. Shipping one kilogram of tomatoes 5,000 kilometers north by semi-truck expends only 1,865 kcal of energy. Today, with the superhighways and high energy costs, light is considered the most important factor for greenhouse vegetable production, rather than locating close to a population center.

In the United States and Mexico, the highest light levels are in the Sonoran desert regions of the two countries (Table 1). This is especially important to know if a grower is to grow greenhouse vegetables during the winter, when tomato, pepper and cucumber prices are at their highest. Generally, a 1 percent decrease in light is a percent decrease in a yield.

Table 1. Solar Radiation Comparison - PAR (Mols/M^2)

<table>
<thead>
<tr>
<th>Location</th>
<th>Dec</th>
<th>June</th>
<th>Oct-Mar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tucson</td>
<td>23</td>
<td>63</td>
<td>195</td>
</tr>
<tr>
<td>Miami</td>
<td>25</td>
<td>44</td>
<td>187</td>
</tr>
<tr>
<td>San Diego</td>
<td>21</td>
<td>48</td>
<td>172</td>
</tr>
<tr>
<td>Colorado</td>
<td>17</td>
<td>58</td>
<td>153</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>10</td>
<td>46</td>
<td>100</td>
</tr>
<tr>
<td>Ohio</td>
<td>8</td>
<td>48</td>
<td>92</td>
</tr>
<tr>
<td>New York</td>
<td>6</td>
<td>44</td>
<td>78</td>
</tr>
</tbody>
</table>

In the last 15 years, a total of over 1726 ha. of greenhouses have been built in the United States, Canada and Mexico. More hectares are planned. Growers from Canada are wishing to establish operations in Mexico specifically for market in Canada in order to compliment existing production occurring in spring to late fall. There is increasing attention being given to continuous supply of product. For the Canadian growers to accomplish this, they are looking at the high light regions of America and Mexico to meet their winter needs.

To establish a greenhouse in a high light region will offer an opportunity to produce over 750 tons of tomatoes/hectare/year. Producing such yields in northern latitudes is only possible if the crops are grown through the summer period, a period when market prices are at their lowest.

Elevation is an important factor in regard to temperature. For example, if tomatoes are selected as the crop to be grown year-round, low elevations in Arizona would be avoided, due to the difficulty in maintaining desirable temperatures in the greenhouse during late spring and early fall, even with fan and pad cooling. In the late 1960’s, hydroponic installations were installed in low elevation regions in both Texas and Arizona. In most regions of Texas, evaporative cooling is mostly ineffective due to high ambient humidity. This coupled with insect and disease problems along with high amortization
costs, especially when growers were purchasing turnkey greenhouse systems rather than building their own growing system, caused most hydroponic installations to fail financially. This was true not only in Texas and Arizona, but throughout the United States. Today, this is also true for many areas of Mexico.

Future hydroponic growers will be selecting sites that are of specific elevation, that historically have summer temperatures low enough not to require excessive amounts of evaporative cooling. At the same time, selecting an elevation not too high is equally important in order not to face high heating costs in winter. In southern Arizona and Northern Mexico, such an elevation for tomato production would range from 1300 to 1800 meters and for cucumber production, 650 to 1300 meters.

Computer control can operate hundreds of devices within a greenhouse (vents, heaters, fans, hot water mixing valves, irrigation valves, curtains, lights, etc.) by utilizing dozens of input parameters, such as outside and inside temperatures, humidity, outside wind direction and velocity, carbon dioxide levels, and even the time of day or night. Unlike early hydroponic installations, computers are used today to collect and log data provided by greenhouse production managers. A computer can keep track of all relevant information, such as temperature, humidity, \( \text{CO}_2 \), light levels, etc. It dates and tags the information and stores it for current or later use. Such a data acquisition system will enable the grower to gain a comprehensive understanding of all factors affecting the quality and timeliness of the product.

While there are many types of growing systems, the three most popular growing media today are coconut coir, rockwool and perlite. In the future, growers will provide little root volume in order to not only reduce media cost, but also to maximize control over mineral nutrition, pH, aeration, and root diseases. Unbelievably high salt levels are maintained in the root systems where the E.C. of the feed solution will approach 3.5 and the drain water at an E.C. of 4.5 to 5.0. This helps to control plant growth and flavor of the tomato fruit. All systems in the future will be closed, with no drainage, preventing any loss of mineral elements and the contamination of groundwater. For health reasons, there is interest in using hydroponic systems to gain control over high nitrogenous levels in leafy vegetables at harvest. This is especially true in Europe for such crops grown under low winter light intensities.

Today integrated pest management (IPM) is of particular interest to North Americans in CEA because of the paucity of pesticides with legal clearance for use in greenhouses. The frightening ability of some pests to develop resistance to chemical pesticides has revived worldwide interest in the use of natural enemies of insect pests, particularly when used in association with horticultural practices, plant genetics, and other control mechanisms. Tomorrow's growers will be growing crops without the use of any chemicals to control diseases and insects. The use of bumble bees for tomato pollination is important in the management plan for not using chemical pesticides. With these insects, pollination is far superior than earlier years when done by hand pollination.
Many early hydroponic growers did not consider cost differences between the types of energy. Many used propane, which proved to be very expensive. The only economical choice is natural gas and fuel oil.

Water quality has become a major concern of greenhouse growers, especially where large amounts of water are applied to a restricted volume of growing medium. Plant growth is affected by the interaction of the dissolved chemical elements in the water supply, the chemical properties of the growing medium to which the water is applied, and the fertility program employed.

In selecting a greenhouse site, a grower must be aware of several chemical properties which might cause problems for greenhouse growers: pH, alkalinity, soluble salts, calcium, magnesium, boron, fluoride, chloride, sulfates, sodium, carbonate, and iron. The cleaner the water, the greater the opportunity to achieve maximum yields. The water designated for use in a greenhouse must undergo an agricultural suitability analysis during greenhouse site selection.

It is especially important to select a site that is free of insects that might be a vector for severe virus diseases. Early hydroponic ventures did not give this consideration. In the United States and Mexico, sites have been selected that have presence of white flies which can be a vector of gemini viruses, which are extremely lethal to most Solanaceae and cucurbit crops. Screens on air intakes and vents must be carefully selected and installed correctly, as the white fly insect almost always gains entry into the growing area. Growing in regions where there are mild winters normally increases the incidence of insects and diseases due to the continued life cycle of the pest. It is important to select a site that isn’t already a major producer of vegetable crops.

The European glass structures, which today are commonly being built for vegetable production in the southwestern part of the United States and Northern Mexico, are very different than the polyethylene/fiberglass houses used in hydroponic production between 1965 and 1990. The height of the European structures is much greater.

To achieve a more uniform growing environment, without rapid temperature fluctuations, more total volume of space is being allotted within a given area of a greenhouse, where today it is common for the gutters of greenhouse structures to reach a height of over 5 meters above ground level.

Whatever the source of energy, it is important to conserve the energy once it is in the greenhouse. In regions of cold winter weather, thermal curtains of porous polyester or an aluminum foil fabric are installed to reduce night heat loss by as much as 57%. In the Sonoran Desert, winter temperatures are not severe enough to warrant curtains. While curtains will provide energy savings, it is not enough to warrant the high cost of the curtains plus the shade from the curtains, even when rolled up and stored during the day, can be a factor.

In conclusion, each crop is very specific in its requirements to environment. To deviate at all will decrease both the desired yield and quality of a product.
Most growing systems will work well horticulturally, but economically, each system can be quite different in cost. Regardless of the type of system, greenhouse agriculture can be extremely expensive. There isn’t any room for mistakes.

The technology of hydroponic systems is changing rapidly with systems today producing yields never before realized. The future for hydroponic/soilless cultured systems appear more positive today than any time over the last 50 years, especially in the Sonoran desert.

C:\AG\Jensen\JENSENMS\BRIGHT Sonora.doc
November 15, 2010