

CHAPTER 3

GENERAL CULTURAL PRACTICES

INTRODUCTION

- *General cultural practices include all information, techniques and skills required to successfully produce a crop and optimize yields – the main goal of any grower!
- *This chapter will concentrate on tomatoes with reference to other crops to illustrate the variability in cultural practices between crops.

CROP AND CULTIVAR SELECTION

- *This is one of the most important decisions a grower will make and depends on:
MARKET... LOCATION... EXPERIENCE

**MARKET:

- *Research the region. Know if there are other growers in the area = competition.
If there are too many tomato growers... try cucumbers, peppers, basil, etc.

- *Know the market. Brokerage houses, grocery vs specialty stores, farmer's markets, restaurants, etc.

- *Hydroponics/greenhouse culture is expensive. Therefore, a high cash-value crop must be chosen. These include:

Tomatoes: Indeterminant (vining) varieties to take advantage of the vertical space in the greenhouse that has been paid for!

Beefsteak: large fruit, harvested individually.

Ex: Trust, Blitz, Quest, Rapsodie, Mariachi.

Cluster, truss or TOV (tomato on the vine): medium to large fruit, harvested as an entire truss.

Ex: Tradiro, Balance, Cronos.

Cherry: small fruit, harvested individually or as an entire truss.

Ex: Micro-Tom, Favorita, Conchita.

Peppers: Colored bells only, primarily yellows – require sun protection.

Ex: Kelvin, Samanta, Cubico, Paramo, TriStar.

Cucumbers: Long (European, seedless, parthenocarpic, burpless).

They are thin-skinned and must be wrapped in plastic after harvest.

Ex: Corona, Discover, Marillo, Millagon, Thor, Odin.

Lettuce: Head, leaf or cos; specialty or bred for hydroponics/CEA.

Ex: Ostinata, Salina, Grand Rapids, Oakleaf, Tango, Summer Bibb or "Limestone" lettuce.

Specialty Greens, Herbs and Medicinals: Several types and varieties.

NOTE: Consult seed companies for suitable crops/varieties.

****LOCATION:**

*The selection of a crop will dictate the best location for the operation...
and visa versa.

Example: If a grower chooses tomatoes in Arizona, the optimum elevation is between 4,000 and 5,000 feet. Any lower and it is usually too hot to grow in the Summers. Any higher and it is too cold to grow in the Winters...UNLESS SIGNIFICANT EXPENSE (\$\$) IS PUT TOWARD COOLING OR HEATING!

Example: If a grower has land at about 2500 feet in elevation in Arizona, a crop that can tolerate warmer temperatures than tomatoes, such as cucumbers could be selected... Or grow different crops in Summer and Winter.

*The selection of a “cultivar” or “variety” is also important when choosing a location.

Seed companies are always coming out with new cultivars (or varieties) to suit different climates and tastes.

With the move of many growing operations to higher light regions of the world ... remember photosynthesis... (Southwest USA, Mexico, Spain, Israel) AND the demand for good quality, good tasting tomatoes year around, many seed companies are introducing more HEAT TOLERANT varieties.

The first tomato variety used by Bonita Nurseries (Eurofresh) in Willcox, AZ about 10 years ago was “MATCH”, then they went to “TRUST”.

TRUST: a Dutch variety (DeRuiter Seed); optimum day temperature = 72 F.

The first 10 acres (and next 30) of greenhouses were passively cooled (no fan and pad/evaporative cooling). They were not able to grow in the Summer and therefore started with transplants (1 month old seedlings started in Canada) in August and removed the crop the following July.

PROBLEM for Bonita:

From June until the following October, when the operation was not producing tomatoes, they would loose their “shelf space” in the markets. This shelf space became increasingly difficult to regain.

SOLUTION for Bonita:

Build evaporatively cooled (fan and pad) greenhouses AND
Do variety trials to determine the best tomato variety for their conditions.

****EXPERIENCE:**

*If a grower has experience with a particular crop... stick with it.

Example: A family with experience in growing long cucumbers in British Columbia, Canada, moved south of Willcox, AZ and is growing cucumbers... not tomatoes.

*If a grower does not have experience with a particular crop...

Work for someone who is successful with that crop to gain experience.
Hire someone who is experienced... an expert!

CROP SCHEDULING

*Plan ahead... When do you want to market your product for the best monetary return?

Arizona hydroponic tomato growers get a better price in Winter –
no field competition and little from greenhouses in northern latitudes.

Alternative: grow year around to maintain stable, consistent market/shelf space.

*Tomatoes: 2 examples of crop scheduling from Bonita Nurseries, Willcox, AZ.

Example 1: Passively cooled greenhouses (vents): No Summer harvesting.

Seed first crop in early July in 1" (or 1.5") Rockwool cubes.

Transplant in mid-July into 3" (or 4" with 2 holes) Rockwool blocks.

Plant 1-month-old seedlings onto Rockwool slabs in August.

Harvest from October until March – Top the plants in February, remove when
second crop begins producing in March.

Seed a second crop in early December as above.

Transplant in mid-December as above.

Interplant new 1 month old seedlings onto Rockwool slabs in January.

Harvest from this new crop from March until July. Remove plants. Clean.

Example 2: Actively cooled greenhouses (fan and pad): Year around harvesting.

Seed, transplant and plant first and second crops as above, removing first crop
as above in March.

Continue second crop, harvesting from March until the next October.

Seed, transplant and plant the third crop, as the first, in July/August.

When third crop is ready to harvest in October, remove second crop.

Continue the process for up to 5 years.

NOTE: Bonita Nurseries does not grow their own transplants. They concentrate
on the production end (growing the plants, harvesting, marketing, etc.)
and purchase 1 month old seedlings from a TRANSPLANT GROWER.

NOTE: Why 2 crops/year? Fruit size and quality go down over time.

GREENHOUSE PREPARATION

*Select a site for the greenhouse that is appropriate for the operation (see Chapter 10).

*Select a greenhouse structure that is appropriate for the operation (see Chapter 11).

*Make sure all equipment is cleaned, serviced and working at optimum efficiency.

*For any crop, incl. tomatoes, the following items must be considered prior to planting:

Good light transmission: Choose the proper greenhouse covering and structure.

If year-around production is planned, shading must be used in Summer.

Adequate cooling: Either passive (vents), active (fan and pad), or both.

Heating is necessary in Winter: NATURAL GAS is the most economical way.

(Other, more expensive, methods of heating: propane, oil, electric, solar.)

Carbon dioxide generation: This is especially important for Winter mornings.

The sun rises, but it's cold. So if fans come on, it's only for a short time.

Plants begin to photosynthesize, using up the ambient carbon dioxide to
the point where photosynthesis is effected and even reduced..

If photosynthesis is reduced, fruit set is reduced – and that's \$\$!

- Ground cover:** Usually white plastic or a white woven material is put down first.
 Reflects light back up into the crop increasing photosynthesis.
 Provides a barrier between the plants and pathogens in the soil.
 Helps to control weeds.
 Allows for ease of cleaning: CLEANLINESS IS PARAMOUNT!
 Trash, leaf litter, etc. is a perfect habitat for bugs/disease.
- Irrigation system:** (see Chapter 8 for details and diagram) This includes:
 Timer/controller to regulate the “fertigation” (water + fertilizer) schedule.
 This will be hard-wired to solenoid valves that open for watering.
 Reservoirs to contain the nutrient solution (full strength or concentrate).
 Injectors (if concentrates are used) to dilute the nutrient solution.
 Distribution tubing/emitters/drainage and/or recycling system.
 Possibly integrated pH (acid/base) and EC (electrical conductivity) probes.
- Overhead support wires:** These need to be strong enough to support the crop
 and high enough (8-14 feet) to make use of the vertical space provided.

ENVIRONMENTAL CONDITIONS REQUIRED (see also Chapter 12)

- *Light:** Two factors are important and can be affected by greenhouse structures and coverings (see Chapter 11). NOTE: Both of these vary with plant species.
- Quality:** Refers to wavelengths of light. (Remember in physics: light spectrum)
 Visible light = 390-760 nm: blue at the low end, red at the high end.
 PAR (photosynthetically active radiation) = between 400 and 700 nm
 (blue, yellow, orange and red... but not green – see Chapter 2)
 NOTE: This varies slightly for each plant species.
- Quantity:** Is affected by both day length and sun angle (changes with season):
 Day Length: In Tucson, AZ day length on June 21 is 14 hours 15 min.
 On December 21 day length, however, is only about 10 hours.
 Sun Angle: Tucson AZ is located approximately 32.5° North, 111° West.
 In June the angle is high = 81° from the horizon (almost overhead).
 In December the angle is low = 34° from the horizon.
 **The quantity (amount) of light reaching the Earth’s surface is therefore
 higher in Summer than it is in Winter.
 **For tomatoes in the desert southwest or other high light areas:
 During the Winter or times of low light the quantity of light
 available is enough to support 3 – 4 fruit/cluster.
 During Spring/Summer/Fall the quantity of light may be too high
 and shading may be needed. 4 – 5 fruit/cluster is typical.
 (See below for physiological disorders related to sun.)
- *Temperature:** The optimum growing temperatures (day and night) vary for different
 plant species and different varieties within a species.
 For TRUST tomatoes (used initially by Bonita Nurseries):
 Germination and post-emergence temperatures = 23-25 C (74-77 F)
 Production optimum temperatures = 22 C (72 F) day/20C (68 F) night.
 Tucson is nearly 2000 feet lower than Bonita and Summer temperatures are
 higher. Therefore, different varieties need to be tested for suitability.

***Relative humidity (RH):** The amount of water in the air compared to the total amount of water that the air can hold at a given temperature.

$$\%RH = \frac{\text{Amount of water in the air}}{\text{Amount of water possible at a given temp.}} \times 100$$

As the temperature increases the amount of water that the air can hold increases. When the air is saturated water molecules condense. This causes clouds when at altitude or fog when near the ground.

How does this relate to tomato plants growing in a greenhouse?

*As the RH increases around the leaf (concentration of water molecules outside increases) it makes it more difficult for the water molecules inside the leaf to move out (transpiration) via diffusion (the passive movement of a substance from high to low concentration – see Chapter 2).

*Therefore, as the RH increases, transpiration decreases, water and therefore nutrient movement decrease, and nutrient deficiencies can result.

*ALSO, as RH increases and transpiration decreases, leaf temperatures often increase, since transpiration is the plant's way of cooling itself.

Optimum RH range for tomatoes (and most plants) = 55% - 95%

In Arizona during hot, dry weather, fan and pad cooling adds moisture to the air.

On hot, humid days, fan and pad cooling adds moisture but does not cool as well.

During cool, damp weather, RH inside the greenhouse can approach 95%.

***Carbon dioxide:** As mentioned earlier, carbon dioxide is critical for photosynthesis and enrichment is most important during the Winter on cold mornings.

Outside ambient levels are around 330 ppm, part per million, (higher in cities due to industrial exhaust products). Enrichment = 800 to 1000 ppm.

***Air circulation:**

This avoids pockets of high or low temperature, humidity or carbon dioxide.

This also reduces the BOUNDARY LAYER (the physical “still air” layer around the leaf) so that proper gas exchange and transpiration can occur.

When cooling fans are off use HAF (horizontal air flow) fans in the upper part of the greenhouse.

***Oxygen:** All parts of the plant require oxygen for respiration (see Chapter 2).

There is usually no problem supplying the top part of the plant with enough.

But waterlogging and high temps. will inhibit oxygen movement to the roots.

PLANT SPACING AND CROP LAYOUT

*Plant spacing is determined by two main factors:

The availability of light to the canopy. Plants must be far enough apart so that a maximum amount of light reaches the leaves for optimum photosynthesis.

The availability of water and nutrients to the roots. Plants must be far enough apart so that all plants have an optimum supply of these items.

*Plant spacing in “vining” greenhouse crops, including tomatoes, is much closer than for field crops.

Example: Field (bush) tomatoes = 4000 – 5000 plants/acre.

Hydroponic greenhouse tomatoes = 10,000 – 11,000 plants/acre.

*Why? A vine has a much smaller diameter than a bush, so they can be closer together and the leaves will still obtain optimum light for photosynthesis.

The roots of a plant growing in hydroponics receives all the water and nutrients it requires – They are “spoon-fed” and do not have to grow large systems.

The roots of a field grown plant will be more spread out as they search for water and nutrients in the soil matrix. Therefore, field grown plants must be positioned far enough apart to avoid competition of neighboring plants for water or nutrients. NOTE: Drip irrigation allows for closer spacing.

*Typical hydroponic plant spacing: Tomatoes = 2.5 – 3 plants per square meter

Peppers = 2.5 – 4 plants per square meter

Cucumbers = 1.25 – 3 plants per square meter

*The typical layout of the greenhouse for vining vegetable crops is in rows tending approximately north and south.

This is important because during the day the sun moves from east to west and if the rows were also set up east to west the southern most rows (in the northern hemisphere) would shade the rows behind them

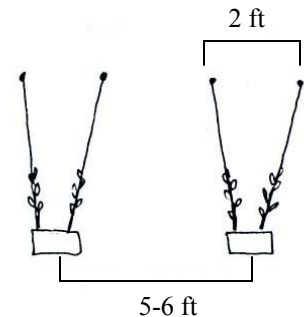
*Typically, tomatoes are also grown in “double rows”.

These double rows are usually 5-6 feet apart.

With 3 plants per Rockwool slab (1 meter long each) or perlite bag (about 36”), sets of 2 slabs/bags are placed side by side.

With 6 plants per slab/bag a single row of slabs/bags is used.

Overhead support wires are set at least 2 feet apart.



TRAINING AND PRUNING

*In general greenhouse crops (tomatoes, peppers and cucumbers) are indeterminate (vining) types to take advantage of the vertical volume of the greenhouse.

*The plant vines are supported on vine twine by vine clips. The twine is wrapped around some sort of device from which it can be unwound (tomahook, bobbin, etc.).

Plants are trained up the twine to the wires forming a “V” shape (see diagram).

As the plants grow up to the overhead support wire, the twine is unwound, the plants lowered and shifted one space – “LEANED AND LOWERED”.

Tomato vines should not be lowered more than 2 feet at a time OR another good way to tell, DO NOT lower the vine such that an 80 or higher degree bend is created in the vine near the floor. High angles promote stem cracking.

*Plants are trained to 1-3 stems by removing (pruning) side shoots or “suckers”.

Tomatoes are trained to 1 stem (or 2 stems to replace a topped or broken neighbor or during a season of high light, i.e., Spring or early Summer).

Peppers are usually trained to 2 or 3 stems. Their stems are much more brittle than tomatoes and tend to snap if they are leaned and lowered.

Cucumbers have traditionally been trained using such methods as the “V-cordon” or “umbrella”. However, they can also be trained to 1 stem like tomatoes.

- *Side shoots or suckers are so named because they suck nutrients from the main plant. The process of removing suckers = “sucker pruning” or “suckering”.
- *NEVER PRUNE SIDE SHOOTS WITHIN 2 INCHES OF THE TOP!
It is too easy to remove the APICAL MERISTEM, the top growing point. If the apical meristem is removed or damaged (the plant is “topped”), a lower side shoot or even a sucker from a neighboring plant will need to be allowed to grow and take over as the apical meristem. This will take time and this plant will now be behind the others. Therefore, STUDY the top of the plant carefully, DETERMINE the location of the apical meristem, MOVE 2 inches down, THEN begin pruning!
- *Extra growths may also occur on fruit clusters. These should be removed.
- *Leaves: As the plants grow old leaves furthest from the apical meristem will begin to age or senesce = yellow spots appear due to the loss of chlorophyll. These leaves are no longer contributing as much to photosynthesis. These leaves should be removed – usually 3 leaves once a week. This is about the usual number of leaves that appear at the meristem per week. The first three leaves will be removed when the plants reach 4-6 feet. Leaves should be removed in the morning when the plants are “turgid” (full of water) so that they break off crisply. Leaves should be removed at the stem-petiole abscission zone – the bulbous point of attachment of the leaf petiole to the main stem. This abscission zone forms a clean break and seals quickly. If the leaf is “ripped” off, the damaged tissue could provide a point of entry for pathogens. NOTE: Removing old, lower leaves also allows for air movement around the lower part of the plant. This reduces humidity that can promote disease. Also, certain insect pests tend to reproduce on lower leaves. Pruning reduces their overall populations. (Ex: white fly – see Chapter 4)

FRUIT PRUNING

- *The plant has a finite amount of mineral nutrients and photosynthates. Removing defective/extra fruits keeps the plant from wasting precious resources.
- *Any fruit that shows defects should be removed. For tomatoes these include blossom end rot (a leathery patch at the blossom end – see Chapter 7), cat facing (hole in the fruit exposing seeds – see Chapter 6), sunscald or green shoulder (a white area caused by overexposure to direct sun – see below), boats (elongation of the fruit – see below) and insect or disease damaged fruit (see Chapter 4).
- *Tomatoes can also set huge clusters – up to 14 fruit or more! Since there is a finite amount of nutrients in the plant, if large clusters are allowed to stay, individual fruit size will usually be smaller within that cluster and clusters higher up on the plant may not receive enough resources resulting in few fruit or no fruit set at all.
- *Recommend: for high light = 4-5 fruit/cluster; for low light = 3-4 fruit per cluster.

FACTORS CONTROLLING PLANT ARCHITECTURE

*Plant growth can be divided into 2 types:

1. **Vegetative growth:** Includes growth of the roots, stem and leaves.
2. **Reproductive growth:** Includes growth of the flowers and fruit.
(Sometimes referred to as “Generative”)

*The plant goes through 3 main stages of growth:

1. **Purely vegetative:** the production of roots, shoot and leaves only.
In tomatoes this stage is about 3 weeks long.
If the grower also seeds and grows the seedlings, environmental and feeding conditions are easily controlled and known.
If the grower obtains the seedlings from a transplant grower, the environmental and feeding conditions may be significantly different from the conditions in the growing greenhouse.
This may cause “transplant shock” and require an adjustment period.
2. **Before maximum fruit load:** vegetative parts continue to be produced but plants also begin to produce flowers and set fruit.
In tomatoes this stage is between 3 weeks and 3 months long.
During this stage the plants will produce between 4-7 trusses. However, this is still considered a “vegetative phase” since the flowers and fruit are a relatively small “sink” for the products of photosynthesis as compared to the vegetative parts of the plant.
3. **Maximum fruit load:** vegetative parts and flowers/fruit continue to be produced, and fruit is also now being harvested.
In tomatoes this phase lasts for 3 to 9 months or more.

*There needs to be a balance between vegetative and reproductive growth:

Vegetative growth is needed for a strong structure (roots and shoot) as well as for good leaf coverage – the sites of photosynthesis.

Reproductive growth is important since this is the reason the grower is raising the tomato (or other fruit bearing) plants in the first place (\$\$)!

*Characteristics of vegetative versus reproductive growth in the tomato:

Characteristic	Reproductive Growth	Vegetative Growth
Leaves	Flat and open, light green, soft	Curled, thick, dark green
Flowering	Close to the top of the plant Flowers open fast and uniform Rapid flowering within truss	Further from the top of the plant Flowers open poorly; sepals stick Poor uniform flowering within truss
Flower Color	Dark yellow	Pale, light yellow
Truss Stem	Thick, sturdy, short and curved	Thin, long and sticking upwards
Fruit	Large, many, good shape and fast development	Small, few, poor shape and slow development

Modified from: DeRuiter Seeds, Inc. Newsletter, Cultural Information, 11/03/97.

*Various environmental or nutritional factors and also different cultural practices can affect the growth habit of the plant. This is known as “Steering plant growth”.

Factor/Practice	Steer towards reproductive	Steer towards vegetative
Difference between day and night temperature	Larger difference	Smaller difference
Day to night cooling rate	Quickly	Slowly or not at all
Position of grow pipe (metal or plastic pipe filled with circulating water running horizontally through the crop)	Three trusses under the top flowering truss	At the level of the truss to be harvested, or turn off
Temperature of grow pipe (0-80 C)	Raise	Lower
Relative humidity	Lower (make dryer)	Raise (make more humid)
Ventilate (where outside temp. is above 10 C)	More ventilation	Less ventilation
Carbon dioxide	Increase (800-1000 ppm)	Decrease
Irrigation: electrical conductivity (salt level) in the drip or input going onto the plants (2.5 - 4 mS/cm)	Higher (or very low) Stress the plant with very low or very high EC (1-1.5 or 3-4)	Lower Moderate EC (2-2.5)
Irrigation: how often and how long	Less frequent but longer duration	More frequent but shorter duration
Irrigation: start time	Later	Earlier
Irrigation: end time	Earlier	Later
Truss pruning	Less (leave more fruit on)	More (remove more fruit)
Leaf pruning	More (remove more leaves)	Less (leave more leaves on)

Modified from DeRuiter Seeds, Inc. Newsletter, Cultural Information, 11/03/97.

NOTE: To keep these factors straight remember that “vegetative growth” is like foliage plants that evolved in the “jungle” under conditions of high humidity, high temperature, no difference between day and night temperatures and more frequent watering.

PHYSIOLOGICAL DISORDERS

*NOTE: Disorders resulting from diseases and insect pests or from nutritional problems will be covered in Chapters 4 and 7, respectively.

*Physiological disorders include noninfectious or abiotic disorders caused by extremes in light, temperature, or soil or root zone moisture, a lack of oxygen, high air pollution, toxicity to pesticides or improper cultural practices.

***Tomatoes:**

Boats = elongated fruit/blossom scar due to improper temperatures (too high or too low) resulting in flower fusion and improper pollination/fertilization.

Cat Facing = breaks in the fruit skin with unfertilized seeds exposed due to abnormally cold temperatures during flowering, high nitrogen levels in the root zone or any mechanical disturbance to the flower during anthesis.

Cracking = concentric rings around or radial cracks from the calyx due to slow-then-fast fruit expansion resulting from wide differences in day/night temperatures, rapid water uptake early in the morning due to high root pressure, or (less likely in hp) a dry period followed by a rain/irrigation.

Flower Drop = flowers may spontaneously fall off due to temperatures over 90 F or below 50 F, drought (not usually seen in hydroponics unless the irrigation system fails), excess nitrogen (not usually seen in hydroponics unless irrigation system malfunctions), low light or too heavy a fruit set.

Gold Fleck = gold spotting due to high temperatures or rapid fruit/plant growth.

Microcracking or Russetting = small fractures in the skin. During the night all plant surfaces cool off. When the air temperature is increased quickly from night to day (a rise of 4-10 degrees) the thin leaves heat up quickly but the fruit stays cool. Like a soda being removed from the refrigerator and set on the counter, the cool fruit acts as a moisture condenser. The condensed water on the skin then causes the microcracking.

Stick Truss = thin, vertical truss with 2-3 fruit at most caused by excessive heat.

Sunscald or Green Shoulder = white, shiny, leathery area caused by sudden exposure to sunlight (due to leaf overpruning, disease, etc.).

***Peppers:**

Cracking (around shoulder; calyx end) = widely fluctuating temperatures.

Flower Drop = too much fruit set or other stresses (temperature, nutrient, etc.).

Glassy Patches = excessive root pressure forces water up bursting cell walls under the fruit skin. Excessive root pressure can result if the air temperature drops significantly faster than the root zone temperature and the roots stay active and force water up through the plant. Also, can occur as a result of THRIPS damage (see Chapter 4).

Sunburn or Sunscald = necrotic (dead) areas, primarily in yellow/gold varieties, caused by direct exposure of the fruit to high light. Allow the crop to develop a denser foliage or use shade cloth/whitewash on the greenhouse.

***Cucumbers:**

Crooking = excessive fruit curvature caused by one or a combination of:
mechanical interference with the growth of the young fruit,
insect damage (i.e., thrips)
adverse temperatures,
high root zone moisture,
poor nutrition or
air pollution (carbon monoxide, ethylene, NO_x gases, i.e., nitrous oxide)

REFERENCE MATERIAL:

1. **DeRuiter Seeds, Inc. Newsletter, Cultural Information.** 11/03/1997. Truss Quality.
2. **Greenhouse Crops in North America: A practical guide to stonewool culture.** 1993. D.H. Marlow. Grodania A/S, 415 Industrial Dr., Milton, Ontario, Canada, L9T5A6.
3. **Growing Greenhouse Tomatoes in Soil and in Soilless Media.** 1991. A.P. Papadopoulos. Agriculture and Canada Publication 1865/E from Communications Branch, Agriculture Canada, Ottawa, Ontario, Canada, K1A0C7. ISBN 0-662-18859-4.
4. **Hydroponic Food Production.** 2001. H.M. Resh. Woodbridge Press Publishing Company, P.O. Box 209, Santa Barbara, CA 93160. ISBN 0-88007-222-9.
5. **Personal Communication:** growers at Bonita Nurseries, HCR 1 Box 145 M, Willcox, AZ, 85643.