

CHAPTER 6

POLLINATION, FERTILIZATION AND BEE MANAGEMENT

INTRODUCTION

- ***As we have seen, many types of crops are grown using greenhouse hydroponics** include tomatoes, colored peppers, long cucumbers, lettuces of various types and other “greens” used in specialty salads, and medicinals (in which flowers, leaves and/or roots are harvested).
- ***For leafy crops or root crops** flowering is unwanted and suppressed. For example, most lettuces are cool weather crops and can be kept in the “vegetative state” (leaves, stems and roots only) if lower air and especially solution temperatures are used. High temperatures will cause “bolting” – an elongation of the main stem and subsequent flowering. This will also cause the leaves to become bitter and unpalatable. For more information on these crops see Chapter 2.
- ***Long cucumber fruit** develop the characteristic slender, smooth appearance because they are not pollinated. If the flowers are allowed to be pollinated the resulting cucumber fruit will be shorter, bulbous and irregular.
- ***Tomatoes and peppers** require pollination and fertilization for fruit development.

PLANT DEVELOPMENT (Review - see Chapter 2, The Plant)

- ***Tomato, pepper and cucumber seeds germinate when moistened.**
 - *A “white root” or radicle emerges growing downward in response to gravity. Tomatoes, peppers and cucumbers all have a “tap root” type root system.
 - *A yellowish “plumular hook” grows upward. When it encounters light the hook straightens and the first seed leaves or cotyledons open and turn green. Tomatoes, peppers and cucumbers are all “dicotyledonous” plants. Dicots have two (di-) cotyledons or first “seed leaves” (vs monocots = grasses).
- ***Tomatoes:** Leaves are compound and develop at each node.
 - 7-12 leaves from the cotyledons, the apical meristem produces a flower cluster or “truss”. After this there are usually 3 leaves between trusses.
 - The truss has a stout stem or peduncle which branches and ends in flowers.
 - There are usually 4-6 flowers per truss, but 1-2 or as many as 10 or more are seen.
 - For beef steak types, in order to maintain a consistent fruit load/harvest, trusses should be pruned to 3 to 5 fruit depending on environmental conditions.
 - Cherry types are not pruned while clusters are pruned as per market needs/variety.
 - The first fruit on each truss is called the “king” fruit.

***Peppers:** Leaves are simple and develop at each node. 7-12 leaves from the cotyledons, the growing point branches producing 1 – 2 flowers. After this the plant branches at each node producing 0 – 2 flowers depending on various factors including nutrition, health of the plant, environment, etc. Each flower/fruit is borne on its own stem attached to the main stem of the plant at the branch point (i.e., peppers do not form trusses). In order to maintain an even fruit load and consistent harvest, some fruit pruning may be required depending on environmental conditions, health of the plant, etc. The fruit that develops at the first branch point is called the “crown” fruit.

***Cucumbers:** Leaves are simple and develop at each node. Depending on variety, environmental conditions, etc., flowers may begin developing at the first few nodes. In order to maintain an even fruit load and consistent harvest prune to 1 fruit/node. In northern or low light areas all initial flowers/fruit should be removed up to a height of 80 – 100 centimeters (2.6 – 3.3 feet) to encourage root growth that will later support fruit production. In high light more initial flowers/fruit may be left. Each flower/fruit is borne on its own stem attached to the main stem at a node.

***For all plants:** The green leaves are “sources” of “photosynthate” (carbohydrates formed during photosynthesis) while the roots, growing tips and fruit are all “sinks” (where the photosynthate will be used for new growth and tissue metabolism).

*Note that if any plant is under stress (temperature, water, nutrient, etc.) or has too much fruit load, it will drop flowers and/or fruit to compensate.

*Environmental stresses can be dealt with in the controlled environment of the greenhouse. However, fruit load needs to be controlled by the grower in the form of “fruit pruning” to maintain a balance between vegetative (leaf and stem) growth and reproductive (flowers and fruit) growth (see Chapter 3 – Steering The Plant).

THE FLOWER

Tomatoes and Peppers:

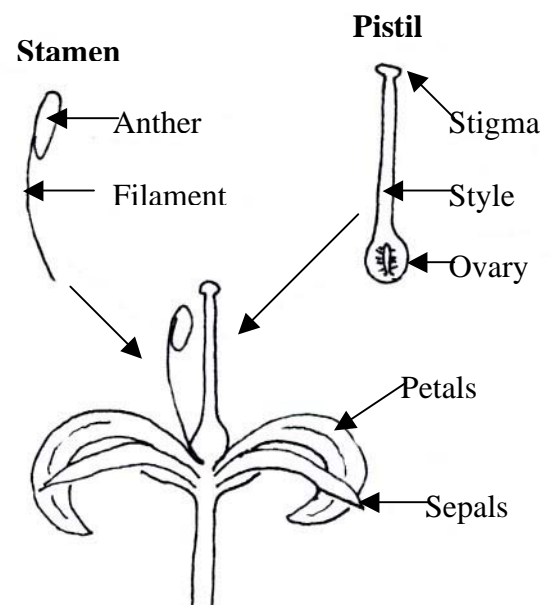
*Flowers of these plants are “complete” (having 5 sepals, 5 petals, stamens and pistil).

*Sepals = green leaf like structure (calyx)

*Petals = bright yellow in tomatoes, white in peppers (corolla)

*Stamens = male organ composed of the filament and anther (they surround the pistil)

*Pistil = female organ composed of the ovary, style and stigma



***Two processes must be completed in order to initiate fruit development:**

***Pollination** = transfer of the pollen from the male anther to the female stigma.

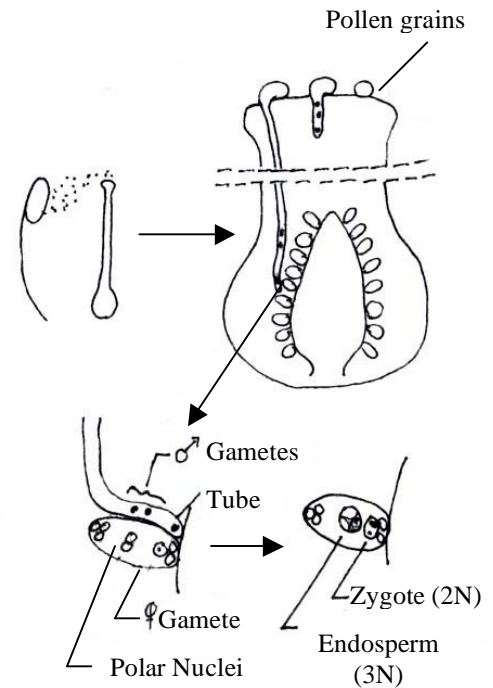
The pollen grains germinate.

The pollen tubes grow down the style to the ovary.

***Fertilization** = a two part process:

1. The union of one of the male gametes with the female gamete (ovule) = zygote (2N)

2. The union of the second male gamete with the 2 polar nuclei = endosperm (3N)



Cucumbers:

*Cucumber flowers are “imperfect” having only male or female flowers. Both male and female flowers are yellow with 5 petals.

*Male and female flowers are borne at nodes on the main stem; 3-5 per node for male flowers, 1-3 for female flowers.

*Male flowers have no pistils but 3 stamens, two with two anthers each and one with one anther.

*Female flowers have reduced and nonfunctional stamens but well developed pistils with three bilobed stigmas, a style and a three-chambered ovary.

*There are several different “sex types” in cucumber flowers and in cucumber plants (see Chapter 2, The Plant, for detailed descriptions).

*Since pollination/fertilization of flowers in long cucumbers is not wanted and will cause abnormally lumpy growth, most growers choose either a “gynoecious” plant (with only female flowers), or a “predominantly female” plant (with mostly female but some male flowers)

ENVIRONMENTAL CONDITIONS NEEDED FOR GOOD POLLINATION

***Proper environmental conditions** are crucial for successful pollination and fertilization fruit-bearing crops including tomatoes and peppers.

***Optimum conditions** will vary with crop chosen and with type and variety used.

***Temperature:**

*Above the optimum temperature range for a particular crop/variety
- the pollen grains can be damaged and may not germinate or have enough energy for pollen tube growth.

*Below the optimum temperature range
- the growth of the pollen tube will be slowed and the pollen grain may run out of energy before reaching the ovary.

***Relative Humidity:** A typical optimum range for many crops is 55 – 85 or 90 %.

*Above the optimum RH range
- the pollen may be too sticky to release properly from the anthers, or
- the pollen grains may clump on the surface of the stigma resulting in uneven pollination and fertilization.

*Below the optimum RH range
- the pollen grains may become desiccated, or
- the stigma surface may be too dry for the pollen grains to stick to it.

***Light:** Several days of cloudy weather will decrease photosynthesis and production of photosynthates. This will slow the development and germination of the pollen and cause poor fruit set.

***Example: A beef steak type tomato**

Optimum temperature range for “Trust” tomatoes:	60 – 85F
Optimum relative humidity range for “Trust” tomatoes:	60 – 80%
Optimum light levels:	Sunny

ABOUT POLLINATION

*Pollination must be done when the flowers are fully open and “receptive” = anthesis.
In tomatoes the petals are curled back, in peppers the flowers are fully open.

*Tomato flowers are usually receptive for two days, therefore pollination should take place at least every other day.

*Problems with pollination and/or fertilization can cause “cat facing”

Uneven pollen distribution on the stigma results in some ovules not getting fertilized. Since hormone secretion from the developing seeds is what causes fruit development, sections of the fruit do not develop resulting in “holes” in the fruit with unfertilized ovules visible.

- *Tomato flowers do not produce nectar and therefore attract few “pollinators”.
In nature they are normally pollinated by shaking action of the wind.
Since there is little wind in the greenhouse the flowers must be pollinated by flicking or tapping the flower stems or by using a vibrator such as an electric toothbrush or a hand-held battery-operated pollinator.
However, in a large commercial facility, bees are commonly used (see below).

POLLINATORS FOR GREENHOUSE VEGETABLE PRODUCTION

- ***Bumble bees** are used routinely for pollination of tomatoes, peppers, blueberries, strawberries and other small fruits and orchard crops.
Honey bees are not effective since they can “communicate” about and fly to other pollen/nectar sources outside the greenhouse. Research has been proposed to test the effectiveness of native southwest carpenter bees as pollinators in greenhouses.
- ***The species *Bombus impatiens*** (native to the Eastern United States) is available from several companies but are reared by the Dutch company “Koppert Biological Systems, Inc.” (28465 Beverly Rd., Romulus, MI 48103 1-800-928-8827).
Normal life cycle = Queen bees hatch in the Fall, mate and “winter over”.
In Spring a queen forages for nectar and pollen and lays her first eggs.
When the first eggs hatch these female workers continue foraging.
The queen continues to lay eggs and workers hatch through Summer.
In Fall new queens (& drones – short-lived for mating only) hatch.
Queens mate outside the colony. New fertile queens begin the cycle again.
NOTE: All worker bees in the hive are female.
- ***The hives** contain 50 – 100 worker bees to pollinate the crop, a laying queen and a developing brood. They are called “NATUPOL” hives for “Natural Pollinators”.
Hives contain a bag of sugar solution since tomato flowers have no nectar.
- ***There are two standard sizes of hives plus the “research” hive:**
Class “A” hive: Used in greenhouses of 15,000 sq.ft. to half an acre.
These last 8 – 12 weeks before needing replacement.
Class “B” hive: Used in greenhouses of 5,000 to 15,000 sq.ft.
These last 6 – 10 weeks before needing replacement.
Smaller “research” hives are available for schools, research projects, etc.
Hives obtained in the Fall or Spring can last 3-4 months.
Hives obtained in Winter (bees normally in hibernation) may only last 4-6 weeks.
- ***Ship bees** “next day air” and keep them between 60 and 80 F until they are placed in the greenhouse (greenhouse temperatures should be suitable for them).
- ***DO NOT TAP ON THE BOX!** This disturbs the bees. Remove the box top to view the bees through the plastic top. There is cotton insulation covering the comb.

***Placing the hive:**

- *Normally place the hive on a stable, horizontal stand or bench between the plants at the beginning of an aisle.
- *Shade from direct, bright sunlight, especially if greenhouse temp is above 85F.
- *Do not put hive near fans. Use a min. of ¼” mesh screen on fans to protect bees.
- *Direct hive entrance away from where people gather to avoid “conflicts”.
- *Keep hive away from carbon dioxide sources. High levels reduces bee activity.
- *Ants can be attracted to the hive. Protect the hive from ants.
 - 1) Apply glue or grease to the legs of the hive support.
 - 2) Remove routes such as overhanging leaves.
 - 3) Place the hive supports in containers of water to create a barrier.

***Once the hive is placed in a secure location:**

- *Enclosed instructions describe how to open the sugar water reservoir. Make sure this “bee happy juice” is available to the bees, otherwise they will die.
- *Open the flight door (a plastic plate on the side of the box). Push/pull the plate upwards until the lower two flight holes are open.

NOTE: Because this bumble bee is not native to the southwest the holes are slits, big enough for the workers to get out but too small for the queen. These are called “queen excluder doors”.

NOTE: Hives come with a plastic mesh over the exit door. It will take the workers 30 – 60 minutes to chew through this. This will give the bees time to acclimate to their new surroundings and will give the grower time to vacate the area before the bees begin to emerge.
- *If the flight door is pushed down part way, one hole will be open. This is called the “bee home” position. Due to the engineering of the holes, once a bee enters this single hole it can not get back out. Within 1 – 2 hours after setting the flight door in the “bee home” position all bees should be back in the hive. (This is important if the hive must be moved.)
- *Pushing the flight door all the way down closes the hive completely.

NOTE: Remember to re-open the flight door so the bees can forage. Forgetting this can kill the colony!

***The bees find “receptive” flowers** (the pollen is mature and ready to shed) by smell.

The bees will only visit receptive flowers.

Also, they “see” in the ultraviolet wavelengths of light. Therefore, anything that blocks UV light from entering the greenhouse can, for a time, disrupt their foraging and ability to pollinate. Ex.: Certain glazings block UV light.

***The bumble bee pollinates a flower** by clamping onto the anther cone with its jaws and rapidly shaking the flower = “buzz pollination”. Within a few hours a pair of dark spots appear on either side of the anther cone where the bee clamped on.

***Pollination and subsequent fertilization** of flowers happens “by accident” as the bees collect pollen to feed themselves, the queen and the developing brood.

***Tomato and pepper flowers** are “self pollinating”. Pollen from the anthers can be transferred to a stigma on the same flower and pollination/fertilization will take place. (As opposed to “obligate outcrossers” that require the pollen from flowers on one plant to be transferred to stigmas on flowers of another, separate, plant.)

***Check the “pollination percentage”** (measure of how many flowers have been visited)

- 1) 1-2 times/week: Either remove 30 – 50 flowers that have closed within the last day OR observe 30 – 50 flowers that are still on the plants.
- 2) Check for the dark spots on the anther cones that indicate bee visitation.
- 3) Pollination percentage = # of marked flowers/total # of flowers counted x 100.
- 4) Pollination percentage should be 80 – 100%.

***Low pollination percentage** may be due to:

- *Toxic chemicals that kill the bees.
- *High temps (above 85F). Bees stay in the hive to fan and cool the brood.
- *Low temperatures (below 60F). Bees stay in the hive to keep the brood warm.
- *Too many flowers for the size of hive (purchase the proper number of hives) or too many flowers due to a bright period following a cloudy period which causes a flush of flowers (the bees will catch up within a couple of days).
- *An expired hive (see above under “Sizes of hives”).

***NOTE:** If a hive is placed into a small greenhouse (less than 5,000 sq.ft.) or a hive is obtained before enough flowers are open there may be more bees than can be accommodated by the number of flowers present. The anther cones will appear brownish black and withered. In this case, food grade bee pollen from a health food store can be introduced onto the center of the plastic top cover (1 teaspoon to 1 tablespoon every few days). Store extra pollen in a freezer.

***When using bees** chemical pesticides should not be used in the greenhouse. Bees are very sensitive to pesticides. However, if surfactants, neem extract or other organic compounds need to be applied, set the flight door in the “bee home” position at least 2 hours before closing the door. Then remove the hive to a safe, stable location between 65 – 70F but not for more than 3 days. Make sure the hive is returned to the same location and orientation in the greenhouse and the flight door is opened.

***Bee stings:**

To avoid stings:

- DO NOT use strong smelling compounds including alcohol, perfume, scented soaps or deodorants or other chemicals. Bees are sensitive to smells.
- DO NOT move quickly near the hive. Bees are agitated by rapid movements.
- DO NOT stand in front of the hive or in their flight path. The bees may run into you, become confused and sting you.

If someone is stung:

- Make sure the person is not allergic to bee stings (if so call for medical help).
- Applying a cold pack tends to reduce swelling and pain.

REFERENCE MATERIAL:

- 1. Growing Greenhouse Seedless Cucumbers in Soil and in Soilless Media.** 1994. A.P. Papadopoulos. Agriculture and Agri-Food Canada Publication 1902/E from the Communications Branch, Agriculture and Agri-Food Canada, Ottawa, Ontario, Canada, K1A 0C7. ISBN 0-662-22118-4
- 2. 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, K1A 0C7. ISBN 0-662-18859-4
- 3. Hydroponic Food Production.** 2001. H.M. Resh. Woodbridge Press Publishing, P.O. Box 209, Santa Barbara, CA, 93160. ISBN 0-88007-222-9
- 4. Koppert Biological Systems Informational Handout.** Supplied with every shipment of bumble bees.
- 5. Peppers as a Commercial Crop: Grower Guide No. 3 – 2nd Series.** 1995. Edited by P. Rogers. Grower Books, Nexus Media Limited, Swanley, Kent, BR8 8HY. ISBN 1-899372-03-2