9 Greenhouse Drip Systems

This chapter provides some general guidance on trickle irrigation system design and scheduling for greenhouse crops.

The greenhouse systems discussed in this section are controlled environment systems. The design and selection of a greenhouse irrigation system is dependent to some extent on the type of greenhouse structure. Structure designs which limit air infiltration have an effect on the amount of moisture retained in the greenhouse. "Tighter" greenhouses will have higher humidity levels. This could lead to the following undesirable results:

- Increased dampness inside the greenhouse which may induce weed, insect, and disease problems.
- Water condensation inside the greenhouse may reduce natural light levels which may lower production.
- Condensate dripping from the roof could damage ornamental foliage and cause fruit damage.
- Plant growth may be reduced.

To overcome the humidity problems, increased ventilation and heating are often used. Humidity can also be reduced by limiting the amount of excess water entering the greenhouse. An efficient irrigation system would deliver the plant water requirement uniformly through the growing media with minimal overdrainage. Many greenhouses now use recirculation systems that collect and reuse the overdrainage from greenhouse irrigation systems. Removing the excess water quickly will reduce ventilation needs and energy requirements.

9.1 Greenhouse Crop Water Requirements

The water requirement of a greenhouse crop will depend on the type of soil or soil mixture, size of the container or bed and many of the other factors listed below. A leaching requirement (overdrainage) of 25 - 50% should be added to the daily crop water requirement if the overdrainage is not collected and recirculated through the greenhouse. This overdrainage is required to ensure adequate leaching of salts and to achieve a good fertilizer distribution when fertigating.

The amount of water required by greenhouse crops is effected by:

- the crop growth stage
- fruit load
- solar radiation
- light intensity
- time of year (i.e. winter vs spring or summer production)
- the amount of nutrient feeding required
- the number of emitters per plant
- the container size
- overdrainage or leaching requirement if not recirculated
- and the type of soil mix or culture used.

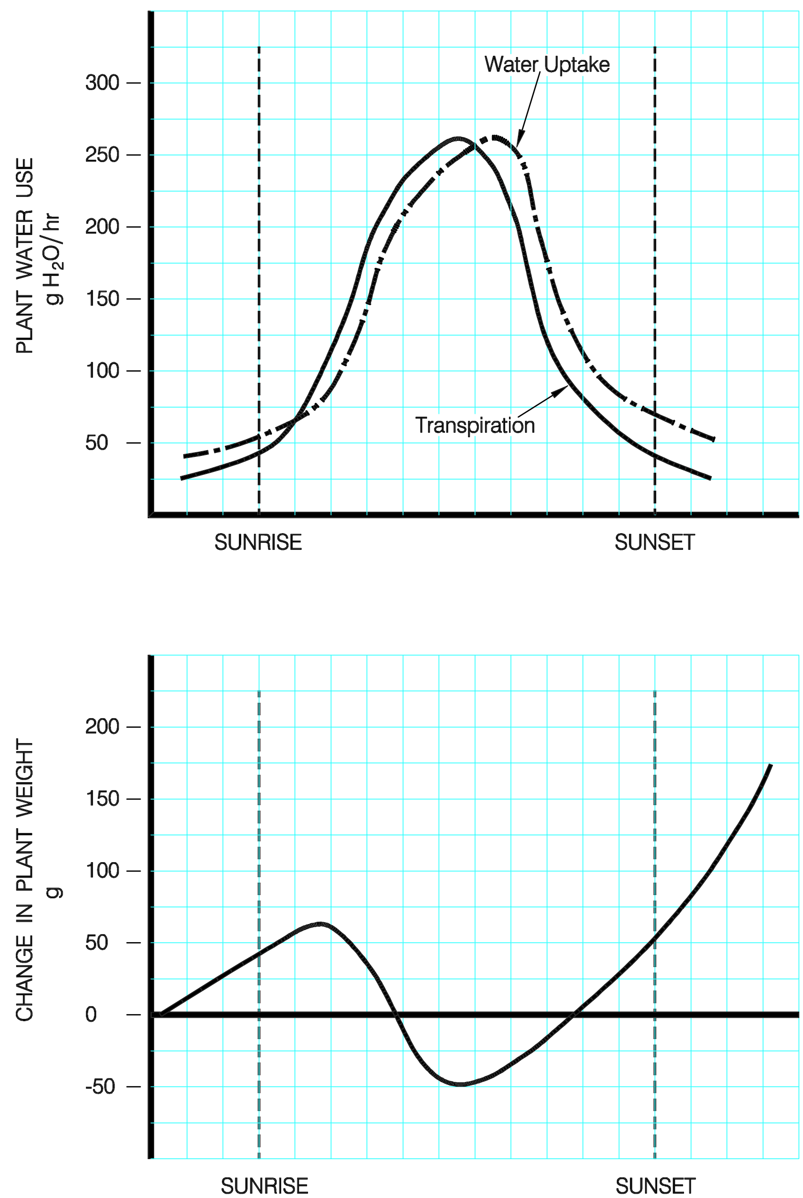

Figure 9.1 *Greenhouse Crop Water Balance*

Irrigation is critical to crop growth and production. The plant itself is 90% water and transpire continually in order to keep cool. Figure 9.1 shows the transpiration and water uptake pattern during the day. Note that the water uptake lags behind the plant transpiration, resulting in the plant losing weight during the peak of the day but regaining the weight after sunset.

Table 9.1 can be used to determine if the greenhouse water supply has adequate capacity during the peak of the season. Caution should be taken in the use of these values as requirements can change depending on the location and orientation of the greenhouse to the sun. Growers must consider their specific greenhouse orientation, construction, cropping system, lighting, radiation and drip system when developing a schedule. Extra emitters may be required along the greenhouse walls, especially on the south side.

The daily values in Table 9.1 indicate the peak consumptive usage of various greenhouse crops. The values shown must be increased to adjust for an overdrain or leaching percentage. This can range from 20 - 50% depending on the type of crop, time of year and even time of day. The planting densities shown are expected at the peak of the growing season. The Greenhouse Vegetable Production Guide provides additional information on the leaching requirements for different crops.

Section 9.2 can be used to determine the annual water requirements for a greenhouse system.

The overdrain requirements should be monitored throughout the day. A general guide to overdrain requirements for greenhouse crops at different times of the day is shown in Table 9.2. The highest percentage overdrain will occur during peak light conditions. More specific overdrain information is also provided for various greenhouse crops in the next sections.

The following sections can be used as a general guide for determining how much water to apply and the application schedule to use for greenhouse vegetable crops.

Table 9.1 Greenhouse Crop Maximum Daily Water Requirements

Crop	Planting Density	*Peak Water Requirement (No overdrainage)	
Cucumber	1.2 - 1.4 plants/m^2 in sawdust or rockwool culture	6.0 L/m^2/day	1.3 - 1.5 gal/plant
Tomatoes	**2.5 - 3.8 plants/m^2 in sawdust or rockwool culture	6.0 L/m^2/day	0.50 gal/plant
Peppers	3.2 - 3.5 plants / m^2 in sawdust or rockwool	6.0 L/m^2/day	0.5 gal/plant
Bench Crops		16.2 L/m^2	0.4 gal/ft^2
Bedding Plants		20.5 L/m^2	0.5 gal/ft^2
Potted Plants		20.5 L/m^2	0.5 gal/ft^2
Hydrangea		61.5 L/m^2	1.5 gal/ft^2
Chrysanthemums		61.5 L/m^2	1.5 gal/ft^2
Roses		29.1 L/m^2	0.7 gal/ft^2 of bed area

** An overdrainage or leaching factor for the day must be added to the values shown to determine total dailywater use. Designers must select an overdrainage factor that is appropriate for the system and crop selected.*

*** Tomatoes start with 2.5 plants/m^2. Extra heads are added as light levels increase. Summer density is 3.8 heads/m^2.*

Table 9.2 Overdrain Requirements

Time	% Drainage
7 a.m.	0%
9 a.m.	3%
10 a.m.	6%
11 a.m.	12%
noon	30%
1 to 3 p.m.	25%
5 p.m.	10%

Cucumber

Cucumbers can have single or double growing cycles per season. Plant and water management strategies will differ depending on the growing cycle used. Upon planting out, place the emitters at the edge of the rockwool block. Allow two emitters per plant. Keep the emitters away from the plant stem to reduce the potential of crown rot.

For sawdust culture irrigation and feeding applications should be applied frequently. Allow 10 - 20% leaching to ensure soluble salt accumulation does not occur. Leaching requirements up to 50% may be necessary depending on water quality. Start by applying 0.25 gal (1000 ml) per day and increase feeding volumes as sunlight and plant size increase. A mature plant will require 1.0 - 1.75 gallons (4-7 litres) per day. Feeding once or twice during the night reduces plant stress when high heating pipe temperatures are used in the spring. Avoid making the growing media too wet in the morning. Irrigation should be started two hours after sunrise. It is important to avoid root pressure in the early morning.

Table 9.3 provides information on scheduling and management of the irrigation system for greenhouse cucumber crops.

Table 9.3 **Irrigation Management for Greenhouse Cucumbers**

Production Cycle	Irrigation Management
Winter Early spring	• Do not irrigate until 2 hours after sunrise. • When setting out plants ensure that growing media is fully wetted before cutting drainage holes. • Irrigate 1 or 2 times at night when hot pipes are used on clear nights. • Night watering for plants that have reached the wire should be applied prior to midnight or shortly after to prevent root pressure associated problems. • Apply 100 - 120 ml per irrigation. • Daily requirement: ml/day = 3 x solar radiation (joules/cm^2) rule of thumb. • Stop 1 1/2 - 2 hours before sunset. • Check overdrain in AM and adjust the last irrigation at the end of the day and/or the night watering.
Late Spring Summer	• System capacity should be 1.5 L/m^2/hr. • Irrigate on light accumulation once light levels are consistent. e.g. from noon to 4:00 pm - apply 100-120 ml/m^2 for every 100 joules/cm^2. • After 4:00 pm apply 150 ml/m^2 for every 140 joules/cm^2 • Adjust for percentage overdrain required. • Start 1 1/2 - 2 hours before sunrise.
Summer New Crop	• System capacity should be 6 L/m^2/day • Irrigation at least every hour for new crop for first 2 or 3 days in sawdust. • First overdrain by 2nd daily irrigation in sawdust. • First overdrain by 3rd or 4th daily irrigation in rockwool • Initiate night waterings when the stem fruit start to grow, ideally before midnight. • Start and stop times same as late spring/summer.
Fall Crop	• Start and stop times same as early spring • Remove drippers from growing media as plants are removed.

Taken from: Greenhouse Vegetable Production Guide for Commercial Growers

Tomato

The growing cycle for a long tomato crop can be divided into the growth stages shown in Table 9.4. Tomato plants grown in sawdust culture will require frequent watering in bright sunlight, up to six times per hour during peak conditions for mature plants. Emitters should be spaced so that the growing media for each plant is watered uniformly.

Feed volumes for tomatoes will start at 0.10 gallons (400 mL)/plant/day and increase to 0.75 gallons (3000 mL)/plant/day. The peak use rate for tomatoes grown in greenhouses is 0.15 - 0.20 gal/hr per plant (0.5 - 0.75 L/hr.) Table 9.4 provides irrigation management considerations for tomato production.

Table 9.4 Irrigation Management for Greenhouse Tomatoes

Production Cycle	Irrigation Management
Winter	• When setting out plants ensure that growing media is fully wetted before cutting drain holes. • Start 2 hours after sunrise. • A 10 cm x 10 cm rockwool block should be kept at a weight of 400 grams. • Apply 80 - 100 ml per irrigation. • Irrigate 1 or 2 times at night when hot pipes are used on clear nights.
Early Spring	• Start 2 hours after sunrise. • Apply a minimum of 100 ml per irrigation. • Allow a 25% overdrain. • Irrigate a minimum of 6 to 7 times per day (use overdrain as a guide) • Daily requirement ml/day = 3 x solar radiation (> 400 joules/cm^2) • Daily requirement ml/day > 300 ml for light levels < 400 joules/cm^2) • Sawdust requires more water than rockwool. • Stop 2 hours before sunset.
Mid Spring	• Start 2 hours after sunrise. • Allow a 35% overdrain in sunny weather. • Allow 25% overdrain in dark weather. • Overdrain should start by 3rd irrigation cycle in a.m. • For sawdust culture water at night with no overdrain. • Irrigate 1 or 2 times at night when hot pipes are used on clear nights. • Stop 2 hours before sunset.
Summer	• Start 1 1/2 - 2 hrs after sunrise. • System capacity should be > 5 L/m^2/day • Overdrain should be 35%, starting after 10:00 a.m. e.g. from 11:00 to 3:00 p.m. - apply 110 ml/emitter for every 80 joules/cm^2. • Repeat 4 to 6 times per hour. • After 3:00 p.m. apply 110 ml/emitter for every 120 joues/cm^2.. • Repeat 4 to 6 times per hour. • Stop 1 1/2 - 2 hours before sunset.
Summer Fall	• Start 2 hours after sunrise. • Growing media should be slightly drier. • Apply 120 to 150 ml/irrigation, cycle a minimum of once per hour. • Overdrain to be reduced to 5 - 10% in dark weather. • First overdrain should start by the 3rd irrigation cycle. • Reduce irrigation cycles as fruit numbers decline and growing head is removed. • Remove emitters from growing media as plants are removed • Stop 2 hours+ before sunset.

Taken from: Greenhouse Vegetable Production Guide for Commercial Growers

Peppers

The growing cycle for a long pepper crop can be divided into the growth stages shown in Table 9.5. Emitters should be spaced so that the growing media for each plant is watered uniformly.

Feed volumes for pepper will start at 0.10 gallons (400 mL)/plant/day and increase to 0.80 gallons (3000 mL)/plant/day. The peak use rate for peppers grown in greenhouses is 0.15 - 0.20 gal/hr (0.5 - 0.75 L/hr.) Table 9.5 provides irrigation management considerations for pepper production.

Table 9.5 Irrigation Management for Greenhouse Peppers

Production Cycle	Irrigation Management
Winter	• When setting out plants ensure that growing media is fully wetted before cutting drain holes. • Start 2 hours+ after sunrise. • Irrigate 1 or 2 times at night when hot pipes are used on clear nights. • Daily requirement mL/day = 3 x solar radiation (joules/cm2). • Stop irrigation 2 hours+ before sunset.
Early Spring	• Start and stop times same as winter. • Apply 100 - 120 ml/irrigation cycle until March. • Apply 120 - 150 ml/irrigation cycle after March. • Overdrain 25 - 30% in sunny weather - first overdrain on 3rd irrigation. • Overdrain 15 - 20% in dark weather.
Summer	• Start 1 1/2 - 2 hours after sunrise. • Last irrigation cycle at sunset on sunny days. • Last irrigation cycle 2 to 3 hours before sunset on dark days. • Larger drip turns of 150 - 200 mls provide more stable EC in summer and • less blossom end rot. • From 11:00 to 4:00 p.m. - apply 100 ml/irrigation/70 joules radiation. • After 4:00 p.m. - apply 100 ml per irrigation/120 joules radiation. • If daily light accumulation is 3000 joules, irrigate until sunset. • Stop 1 1/2 - 2 hours before sunset.
Fall	• Start irrigation 2 hrs+ after sunrise. • Reduce irrigation cycles as fruit numbers decline and growing head is removed. • Stop irrigation 2 hrs+ before sunset. • Remove emitters from growing media as plants are removed.

Taken from: Greenhouse Vegetable Production Guide for Commercial Growers

The BC Ministry of Agriculture, Fisheries and Food Greenhouse Vegetable Production Guide provides information on planting densities and basic feeding formulas for greenhouse crops.

9.2 Annual Water Requirement

The annual water requirement of a greenhouse crop will be dependent on many of the same factors listed in the beginning of section 9.1. Determining an approximate annual use value will help growers plan storage requirements for greenhouse operations that do not have a reliable water supply. Table 9.6 provides an approximation of the amount of water used by greenhouse crops on a monthly basis. To be conservative, the values shown include 40 % for leaching. The data is given on a square meter basis.

Table 9.6 Annual Water Requirements for Greenhouse Crops

Month	m^3 /m^2	ft^3 / m^2	gallons / m^2
January	0.040	1.41	10.6
February	0.102	3.60	26.9
March	0.106	3.74	28.0
April	0.146	5.15	38.5
May	0.235	8.29	62.0
June	0.262	9.24	69.1
July	0.210	7.41	55.4
August	0.192	6.81	51.0
September	0.138	4.87	36.4
October	0.081	2.86	21.4
November	0.006	0.21	1.60
December	0.012	0.42	3.1
Total	1.53	54.0	404

The information in Table 9.6 can be used to estimate the annual water costs if greenhouse water is metered or to calculate the storage requirements for summer months.

Example 9.1 Water Costs

A grower with a 50 m x 100 m greenhouse obtains water from a private water authority at a cost of \$0.75 / m^3. The annual water cost would be:

50 m x 100 m = 5000 m^2 x 1.53 m^3 / m^2 = 7650 m^3

7650 m^3 x \$0.75 / m^3 = \$5738

Example 9.2 Storage Requirements

A grower with a 50 m x 100 m greenhouse obtains water from a stream with a limited supply. The stream has a limited supply from July on and is dry in August and September. Storage is required from the beginning of July until the end of September.

From Table 9.6 the amount of storage per square meter that is required is:

July	0.210 m^3
August	0.192 m^3
September	0.138 m^3
Total	0.54 m^3

The amount of storage for the 50 m x 100 m greenhouse is:

$$50\text{ m} \times 100\text{ m} \times 0.54\text{ m}^3 / \text{m}^2 = 2700\text{ m}^3$$

The size of the storage pond would be 2.5 m deep x 20 m wide x 54 m long.

9.3 Greenhouse Emitter Selection and Installation

Emitter Selection

Greenhouse crops require low dosages of water to be applied very frequently. The duration of each application can be as low as 75 seconds. Emitters must therefore be very uniform to ensure that each plant receives the same amount of water. Two types of drip systems are presently used in the greenhouse industry.

Microtube Systems

Microtube systems use a small spaghetti tube to deliver water from the lateral to the plant. The diameter and length of the tube will determine how much flow is delivered by the emitter. For these systems it is important to cut the delivery tube to each plant to the same length. Figures 9.4 and 9.5 show the delivery flows for different sizes of microtube. A check should be done at the site to verify the microtube flow rates. See Section 4.5.

Microtube or spaghetti systems are inexpensive but are fully laminar flow. They are therefore more susceptible to plugging and pressure differentials. See Chapter 4 for further information on emitter performance for laminar flow emitters.

Emitter Systems

Emitter systems still use microtubes to deliver the water to the plant but utilize an emitter installed at the lateral to control the flow. The emitter provides better flow regulation than the microtube system. A 2 - 3 L/hr emitter is often used. In this case the microtubes are only used to transfer water from the emitter to the plant. Non leaking emitters can also be used to prevent both the microtube and lateral from draining after each irrigation. This allows for quicker startups, better uniformity and less moisture in the greenhouse.

Figure 9.2 shows the difference between a microtube and emitter system. Figures 9.3 and 9.6 show installation of each of these systems in a greenhouse.

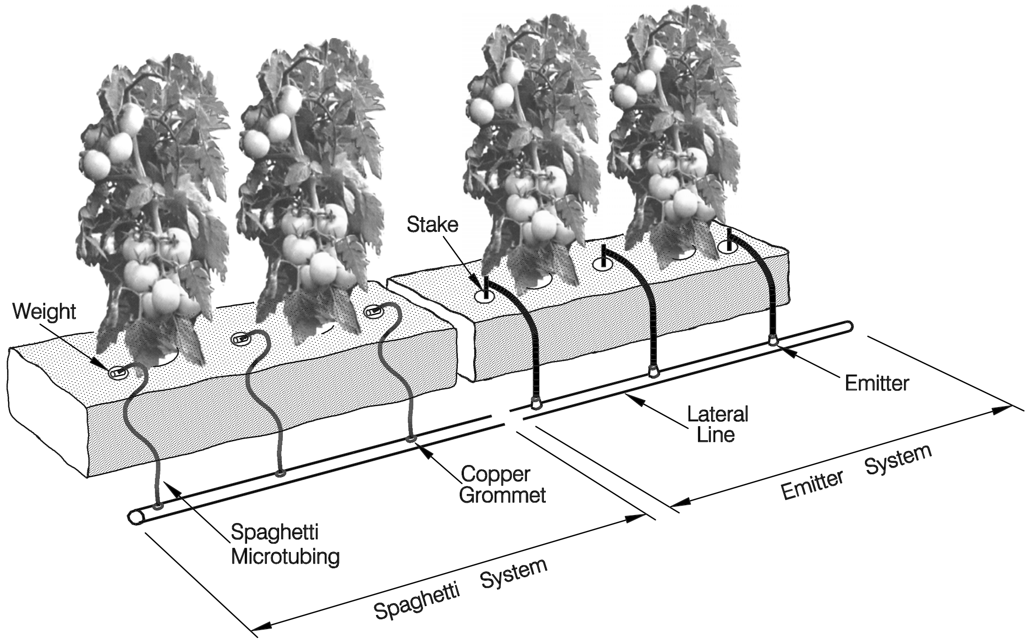

Figure 9.2 *Greenhouse Drip Systems*

Figure 9.3 *Microtube System in Tomatoes*

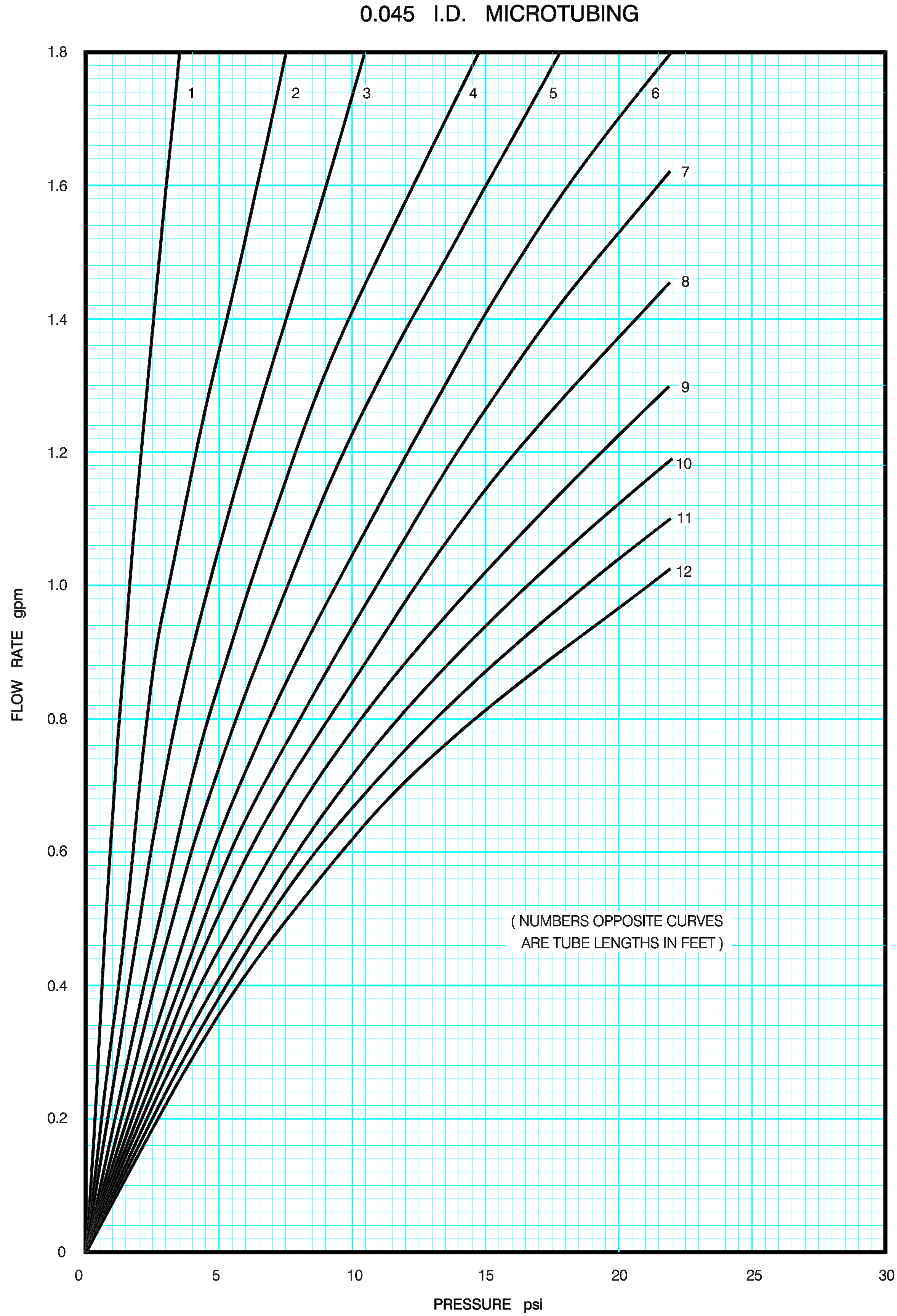

Figure 9.4 *Flow Chart for 0.045 Tubing*

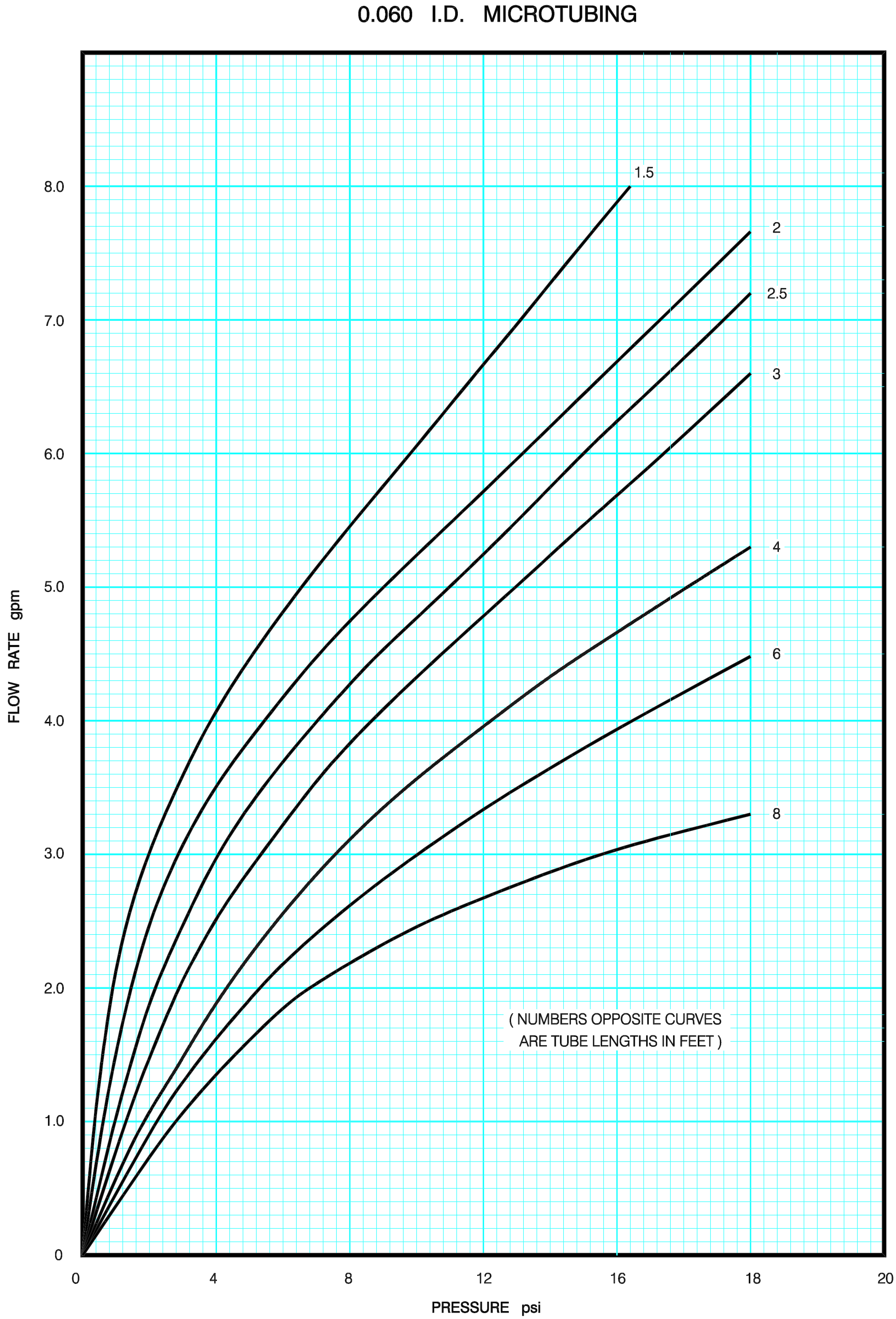

Figure 9.5 *Flow Chart for 0.060 Tubing*

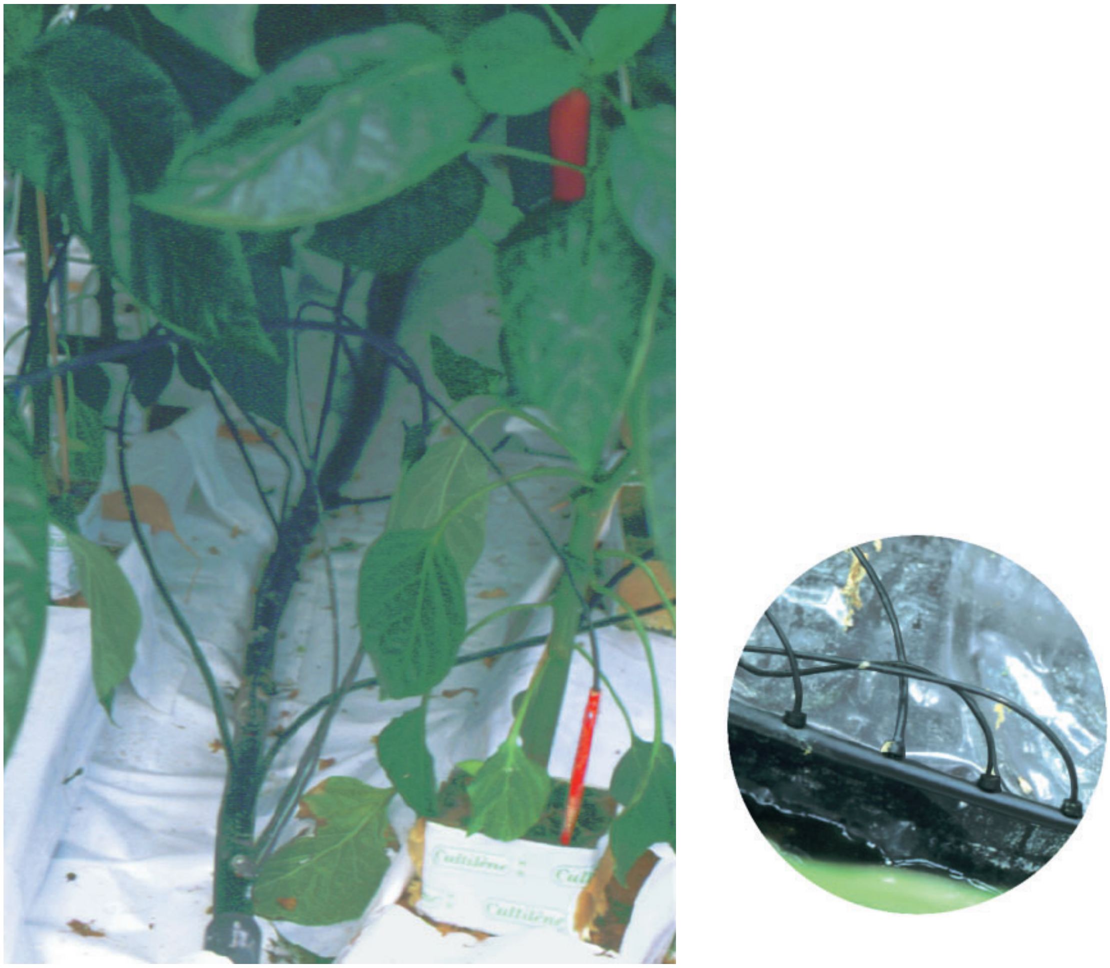

Figure 9.6 *Emitter System in Peppers*

Emitter Installation

An emitter flow rate and the number of emitters per bag must first be determined to calculate the proper line sizing, zone control and pump requirements. The number of emitters per plant can vary depending on the type of growing media and trellising system used.

For plants that are grown in pots or bags, two or three emitters should be installed per bag to ensure adequate moisture distribution throughout the growing media. The additional emitters also ensure that the plants will always get some water should one of the emitters clog. Figure 9.7 shows a drip system operating in a potted floriculture system. Generally emitter discharge rates of 2 - 4 L/hr are selected. Lower emitter rates will usually provide better uniformity as the system can be operated for slightly longer periods of time to apply the same amount of water.

Figure 9.7 *Greenhouse Drip Irrigation System for Potted Plants*

Greenhouse vegetables are grown in various production systems. The most common are single row "V" systems and double row systems. In both cases the growing media, usually either rockwool or sawdust is contained in plastic bags. The plants are started in small containers that are embedded in the growing media. Depending on the size of the plastic bags, two to four plants are embedded in each bag.

In this system only one emitter is installed per plant, however since four plants share one bag there are four emitters supplying water to each bag. The plants can therefore obtain moisture from more than one emitter should one emitter become clogged. Figure 9.8 shows emitter installation in soilless culture. Figures 9.9 and 9.10 illustrate different growing methods for greenhouse crops.

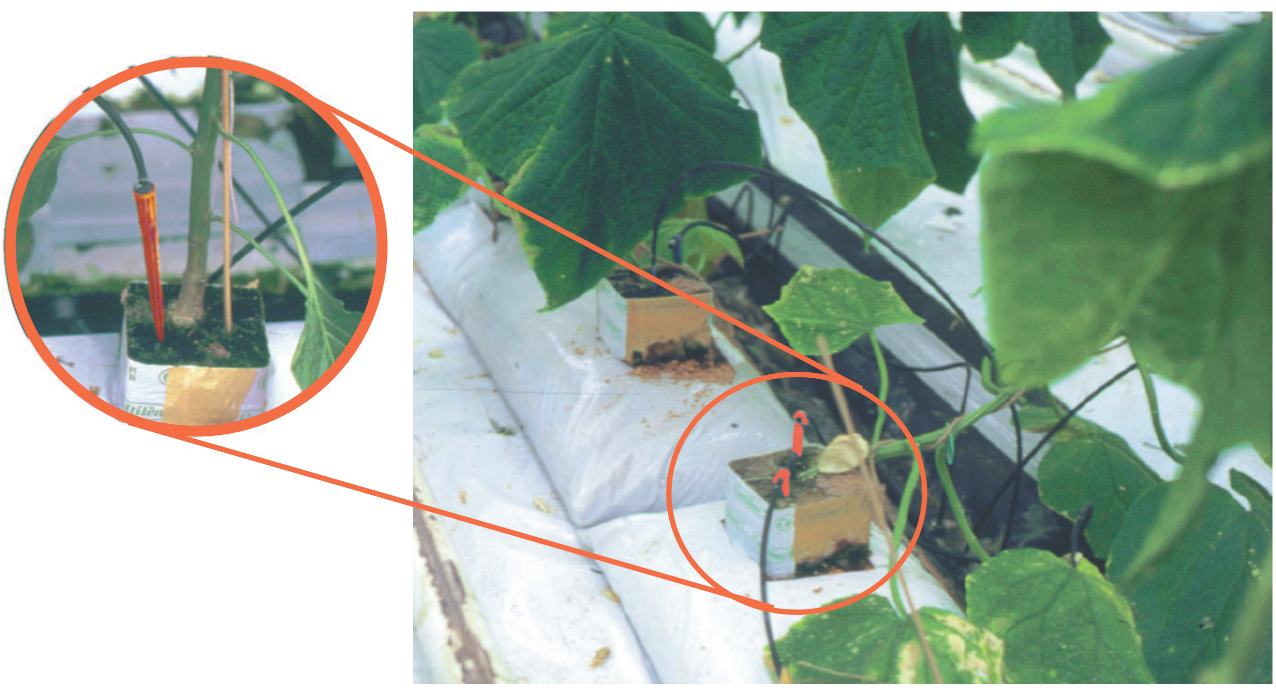

Figure 9.8 *Emitter Installation in Soilless Culture*

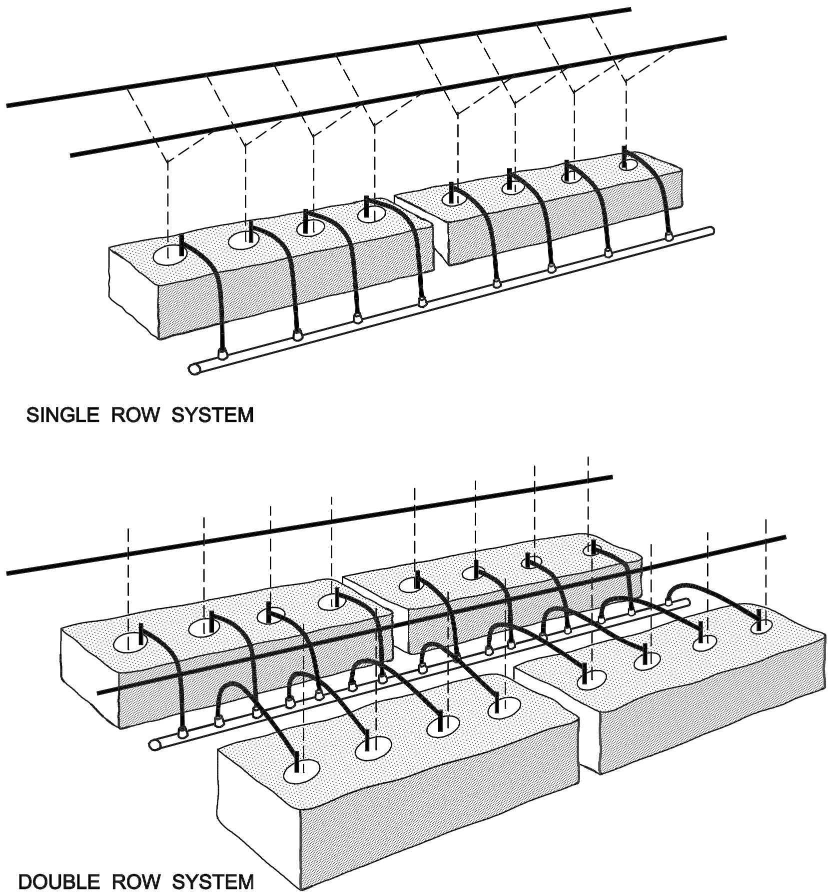

Figure 9.9 *Greenhouse Emitter Installation*

Figure 9.10 *Greenhouse Drip System for Vegetable Crops*

9.4 Greenhouse Drip System Design

Lateral and Header Line Sizing

Greenhouse trickle systems are often used to also supply the plant nutrients. The header and lateral lines must therefore be sized correctly to ensure that water is distributed evenly throughout the entire greenhouse, achieving good uniformity. A coefficient of uniformity of 90% or better should be achieved. Sections 4.2, 4.3 and 4.4 provide further information on system uniformity.

It is important to keep lateral sizes as small as possible while maintaining uniformity. This can be done by keeping laterals short. Since greenhouse trickle systems are operated frequently but for short durations, the fill time requirements as well as lateral seepage during shutdown must be minimized to achieve good uniformity of application. Non leaking emitters can be used to keep lines full at all times. PVC pipes that are exposed to light should be painted to keep light from entering the pipe and promoting algae growth.

The irrigation system should be designed to be able to supply the maximum plant density during the peak of the growing season.

Chapter 8 provides information on how to select and size mainlines and pumps.

Example 9.3 - Greenhouse Drip Irrigation Design

A grower with a 50 m x 100 m greenhouse is producing tomatoes in rockwool media in a single row "v" planting system. The plants are spaced 0.25 meters apart along the row, with 4 plants installed per bag. Two of the plants will be trained with two heads each. In effect there will be six plants per bag supplied by four emitters. The rows are 1.6 meters apart. The plant density in the greenhouse is 2.4 plants / m^2. The emitter flow rate is 4 L/hr.

There is also a 3 m work area that runs through the centre of the greenhouse.

Water to the greenhouse is from a well that supplies 60 gpm. An emission uniformity of 0.95 is desired. The emitter has a C_v of 0.035 and an x value of 0.5. Note that the emitter selected is manufactured to a fine tolerance. This is important if an uniformity of 0.95 is to be achieved.

Figures 9.11 and 9.12 show the plant and emitter layout as well as the entire greenhouse layout. For an initial planting density of 2.4 plants / m^2 and one emitter per plant the number of emitters in the greenhouse is:

$$2.4 \text{ plants} / m^2 \times 50 \text{ m} \times 100 \text{ m} \times 1 \text{ emitter/plant} = 12{,}000 \text{ emitters}$$

Since two plants in each bag will be allowed to develop two leaders, there will effectively be a total of 6 plants per bag instead of four. The final plant density will therefore be 1.5 times the density given above. The final plant density will be 3.6 plants per m^2.

(Continued)

Example 9.3 - Greenhouse Drip Irrigation Design

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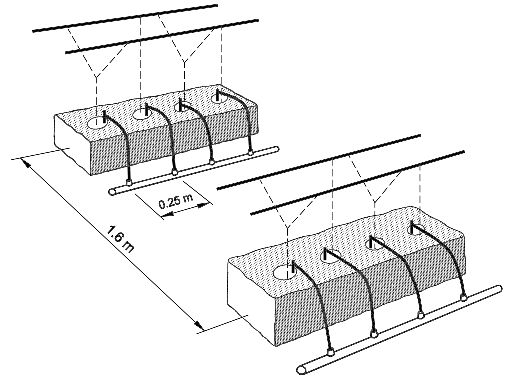

Figure 9.11 Plant and Emitter Layout

Determine the plant and greenhouse water requirement, bulk water storage size, number of zones, lateral size and the submain size.

Plant Water Requirement

Growers usually apply a fixed volume of water to the plant during each irrigation cycle but increase the number of cycles per hour to accommodate plant needs. The amount applied during each cycle is increased as the plant fruit loading increases and the ambient air temperature increases.

From Table 9.4 the irrigation management guide suggests that the amount to apply per irrigation cycle may be as high as 150 ml per plant during peak conditions. Table 9.1 indicates the maximum daily crop water requirement for tomatoes is 6.0 L/m^2/day. On a high consumption day the irrigation system may therefore cycle 40 times or more.

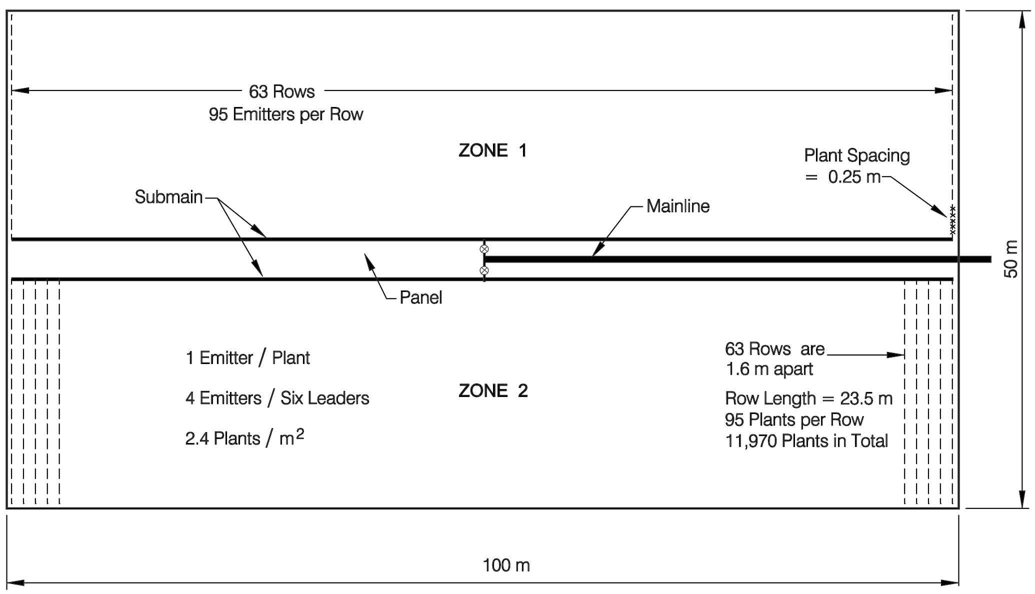

Figure 9.12 Greenhouse Layout for Example 9.3

(Continued)

Example 9.3 - Greenhouse Drip Irrigation Design

Storage Sizing

The bulk water storage should be capable of storing at least one day of water supply. Normally, a two day water storage is selected.

The storage size for two days of peak use will be:

$$50 \text{ m} \times 100 \text{ m} = 5{,}000 \text{ m}^2 \times 6.0 \text{ L/m}^2\text{/day} \times 2 \text{ days} = 60{,}000 \text{ Litres}$$

$$60{,}000 \text{ L} \times \frac{1 \text{ m}^3}{1000 \text{ L}} = 60 \text{ m}^3$$

If a concrete tank is used the storage facility must be at least 4 m x 7.5 m x 2 m deep.

Zone Size

The length of time that a zone must operate for each irrigation cycle to apply 150 ml is:

$$\frac{150 \text{ ml / watering}}{4 \text{ L/hr/emitter}} \times \frac{1 \text{ L}}{1000 \text{ ml}} = 0.0375 \text{ hrs} = 2.25 \text{ minutes}$$

The well supply is 60 gpm. While the system can be set up to operate at larger flow rates pumping from storage, it is recommended that the zone flow rate match the pump output to prevent the storage from being drawn down.

The water supply is 60 gpm = 225 L / min = 13,500 L / hr

The maximum number of emitters that can be operated at one time is:

$$\frac{13{,}500 \text{ L/h}}{4 \text{ L/hr/emitter}} = 3375 \text{ emitters per zone}$$

$$\text{The number of zones} = \frac{12{,}000 \text{ emitters}}{3375 \text{ emitters/zone}} = 3.56 \text{ or } 4 \text{ zones}$$

During the peak of the season up to 6 cycles per hour may be required for each zone. As calculated earlier, each irrigation cycle is 2.25 minutes long. The operating time for each zone may therefore be 13.5 minutes every hour during peak times. Together the four zones will need 54 minutes of operating time each hour. The margin of error is too close. The number of zones should be reduced to allow for additional watering during peak times should it be required. The higher zone flow rate will draw the storage down during peak conditions but it will recover later in the day.

The number of zones should be reduced to three. Three zones cycling 6 times per hour will need 40 minutes of watering per hour, leaving 20 minutes for additional watering if required.

$$\text{Number of emitters per zone} = \frac{12{,}000 \text{ emitters}}{3 \text{ zones}} = 4{,}000 \text{ emitters}$$

$$\text{Flow rate per zone} = 4000 \text{ emitters} \times \frac{4 \text{ L/hr}}{\text{emitter}} = 16{,}000 \text{ L/hr}$$

$$= 70.5 \text{ gpm}$$

Example 9.3 - Greenhouse Drip Irrigation Design *(Continued)*

Lateral Design

The emitter selected will provide 4 L/hr at a pressure of 15 psi. A system uniformity (EU) of 0.95 is required. The emitter selected has a C_v of 0.035 and an x value of 0.5. The layout of the growing media has one emitter installed per plant and four plants per slab. In effect each plant can obtain water from at least two emitters. (n = 2 in the equation below)

From Equation 4.6:

$$Eu_{cv} = 1 - 1.27 \times \frac{0.035}{\sqrt{2}} = 0.97$$

From Table 4.7

For an Eu_{cv} of 0.97, a discharge exponent of 0.5 and an EU of 0.95 the allowable pressure variation between emitters is 10% of the emitter operating pressure. For an operating pressure of 15 psi the allowable pressure variation is 1.5 psi.

The maximum pressure variation should not exceed 1.5 psi in the lateral and header line. It is important that the lateral piping is kept as small as possible to reduce filling time upon start up. The length of each lateral line in this example is 23.5 m or 77 ft.

A single size lateral will be used so the specific discharge curves in Appendix A can be used.

$$SDR = \frac{\text{lateral flow rate}}{\text{lateral length}} \quad \frac{(\text{gph})}{(\text{ft})}$$

lateral flow rate = 95 emitters / row x 4 L / hr / emitter = 390 L / hr

= 100 gph

$$SDR = \frac{100 \text{ gph}}{77 \text{ ft}} = 1.3$$

From Figure A.2

– 77 ft of 16 mm (0.600 in. I.D.) polyethylene at a flow rate of 1.3 gph/ft has a friction loss of 1.50 ft = 0.65 psi

– allowing 30% for emitter barb loss = 0.20 psi

Total lateral loss = 0.85 psi

Header Design

As shown in Figure 9.12, the section of the header line which will affect the pressure uniformity throughout the zone is the portion which runs from the control valve to the last lateral. To improve uniformity the zone control is located in the centre of the zone. The allowable friction loss in this pipe section (x_1-x_2) will be:

Allowable header friction loss = Maximum pressure variation within the zone – lateral friction loss

= 1.5 psi – 0.85 psi = 0.65 psi

(Continued)

Example 9.3 - Greenhouse Drip Irrigation Design *(Continued)*

The total flow rate for each zone is 70.5 gpm. The header line section from the zone control valve to the last lateral (x_1-x_2) has a flow rate of 35 gpm.

Using the procedure from Section 7.4, a single size submain can be designed and selected.

There are 63 rows for each zone. The header must supply a maximum of 32 rows from the zone control point to the end of the header.

The allowable header friction loss is 0.65 psi. In this case there are a lot of fittings in close proximity as the lateral spacing is close together. The fitting loss may therefore be a larger percentage of the total friction loss. Including 40% for fitting loss, the header line friction loss can therefore be separated as:

Pipe friction loss	= 0.60 x 0.65	= 0.39 psi
Fitting loss	= 0.40 x 0.65	= 0.26 psi
		0.65 psi

From Table 7.2 - for 32 outlets, the friction loss factor is 0.349.

The header line pipe friction loss of 0.84 psi for 32 outlets is therefore 34.9% of the pipe friction factor for one outlet at the end of the line.

The submain length is 32 rows x 1.6 m / row = 51.2 m = 168 ft.

The pipe friction loss factor is therefore:

$$\frac{0.39 \text{ psi}}{168 \text{ ft} \times (0.349)} = 0.0067 \text{ psi / ft} = \frac{0.67 \text{ psi}}{100 \text{ ft}}$$

From Table C.2 (Appendix C)

For Section x_1 - x_2 for a flow rate of 35 gpm and a pipe friction loss factor of 0.67 psi / 100 ft a 2” Class 160 PVC pipe is required for the submain.

The actual friction loss for section x_1 - x_2 with a 2 “ PVC header line is:

From Table C.2

2” Class 160 PVC @ 35 gpm = 0.67 psi / 100 ft

For a 168 ft line with 32 outlets the friction loss is

$$168 \text{ ft} \times 0.349 \times \frac{0.67 \text{ psi}}{100 \text{ ft}} = 0.39 \text{ psi}$$

Fitting loss	= 40% of pipe loss = 0.40 x 0.39	= 0.16 psi
Total header loss		= 0.55 psi

The pressure variation throughout the zone will be the sum of the header loss and the lateral loss. In this instance the pressure variation will be 0.85 psi + 0.55 psi = 1.4 psi. The operating pressure range will therefore be 15.7 psi to 14.3 psi. The pressure setting at the zone control should be 15.7 psi.