Vegetable Irrigation

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Basic principles

The purpose for irrigating vegetables is to ***limit plant stress*** -- by maintaining ideal soil moisture throughout the growing season, and especially during the critical periods of crop growth (Table 1). Plant stress causes defects such as misshapen fruit, toughness, strong and off flavors, poor tipfill and podfill, cracking, and blossom-end rot; it increases susceptibility to diseases and pests, reduces soluble solids, and shortens shelf life. When irrigation is correctly/precisely scheduled (1) plants use a minimum amount of their own energy to obtain water from the soil, (2) optimum conditions exist for the best possible plant health, (3) production and quality are maximized, (4) pests and disease are mitigated, (5) energy, water, plant nutrients, and other resources are efficiently utilized and not wasted, and (6) pollution is minimized.

Plant stress will be minimal and yields and quality maximized when soil moisture *content/tension* is maintained in a narrow range *near* field capacity (when the plant can *readily/easily* get soil moisture). At field capacity the soil is moist but water will no longer drain due to the force of gravity. To maintain (all the time) soil moisture *near* field capacity requires uniform, frequent, and precisely timed water applications/irrigations (and good surface and subsurface drainage). For emphasis, more frequent irrigation events of smaller amounts are better than delaying until the soil is dry; the total amount of water required is the same regardless of frequency of irrigation events.

Applying the correct amount of water at the correct time is critical for minimizing plant stress. Irrigation scheduling (i.e., when to irrigate and how much water to apply) is governed by (1) the crop water requirement, termed evapotranspiration, **ET**, and (2) the ability of the soil to hold/release water. The ability of soils to hold and release water is related to texture as indicated in Table 2. ET is (1) the soil water that the crop (including weeds) transpire/give-off, plus (2) the soil water that is drawn to and evaporated through/from the soil surface. Numerous factors govern ET including the amount of solar radiation, day length, air temperature, wind speed, humidity level, crop species, crop growth stage, canopy size and shape, and leaf size and shape.

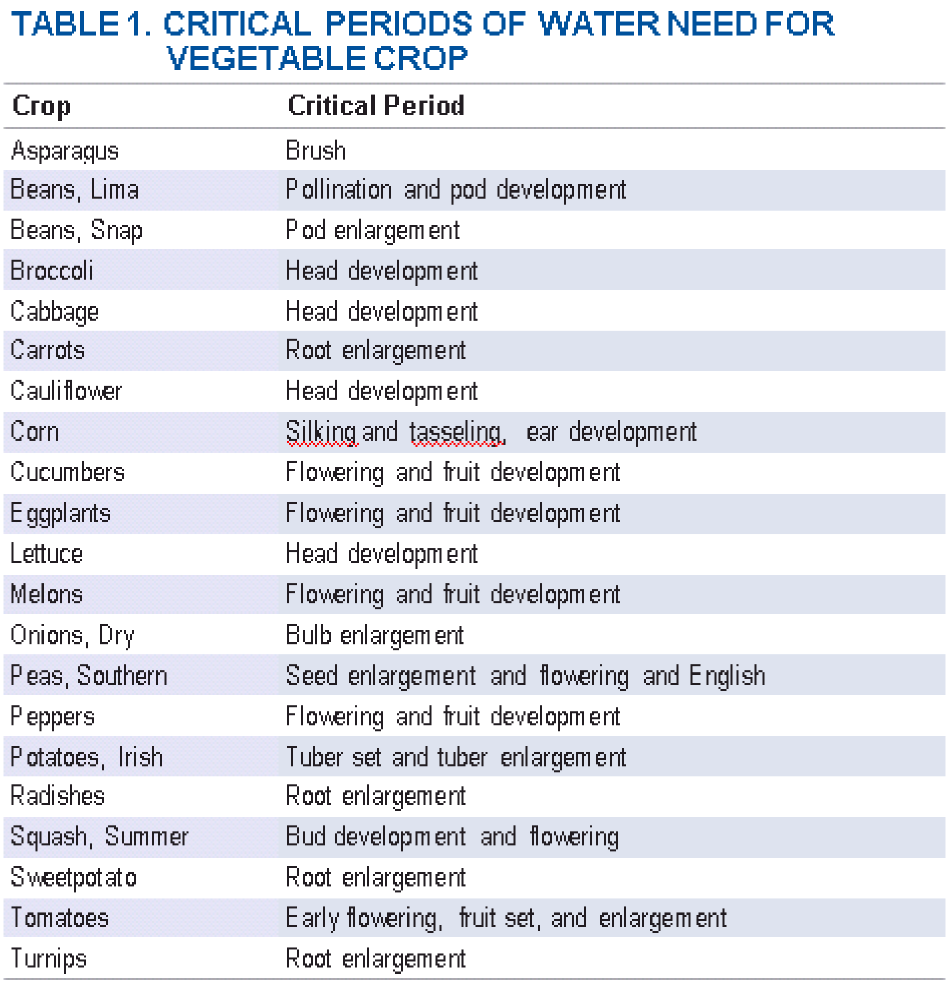


TABLE 1. CRITICAL PERIODS OF WATER NEED FOR VEGETABLE CROP

Crop	Critical Period
Asparagus	Brush
Beans, Lima	Pollination and pod development
Beans, Snap	Pod enlargement
Broccoli	Head development
Cabbage	Head development
Carrots	Root enlargement
Cauliflower	Head development
Corn	Silking and tasseling, ear development
Cucumbers	Flowering and fruit development
Eggplants	Flowering and fruit development
Lettuce	Head development
Melons	Flowering and fruit development
Onions, Dry	Bulb enlargement
Peas, Southern	Seed enlargement and flowering and English
Peppers	Flowering and fruit development
Potatoes, Irish	Tuber set and tuber enlargement
Radishes	Root enlargement
Squash, Summer	Bud development and flowering
Sweetpotato	Root enlargement
Tomatoes	Early flowering, fruit set, and enlargement
Turnips	Root enlargement

From Southeastern U. S. 2014 Vegetable Crop HANDBOOK

Table 2. Maximum Depth of Water to Apply per Irrigation Event and Maximum Sprinkler Irrigation Rate *(partially from Hoffman, et al.).*

* The values in the **Com**mon column were used to compute those in the columns under **Net** Maximum Depth of Water to Apply per Irrigation Event.

Soil Texture	**Total** Plant Available Soil Water (Inches of Water per Foot of Soil Depth)			**Net** Maximum Depth of Water to Apply per Irrigation Event** (Inches of Water per Foot of Root Zone Depth)			**Maximum** Application Rate using Sprinklers**** (inches per hour)			
				Allowable Depletion of Total Plant Available Soil Moisture			Soil Slope (% = feet per 100 feet)			
	Min	Com*	Max	25%***	35%	45%	0-5	5-8	8-12	>12
Coarse sand	0.3	**0.6**	0.8	**0.15**	0.21	0.27	1.97	1.57	1.18	0.79
Fine sand	0.5	**0.8**	1.0	**0.20**	0.28	0.36	1.57	1.26	0.94	0.63
Loamy fine sand	0.7	**1.0**	1.2	**0.25**	0.35	0.45	1.38	1.10	0.83	0.55
Sandy loam	1.3	**1.4**	1.6	**0.35**	0.49	0.63	0.98	0.79	0.59	0.39
Fine sandy loam	1.6	**1.7**	1.9	**0.42**	0.59	0.76	0.79	0.63	0.47	0.31
Very fine sandy loam	1.7	**1.8**	2.0	**0.45**	0.63	0.81	0.59	0.47	0.35	0.24
Loam	1.8	**1.9**	2.1	**0.48**	0.67	0.86	0.51	0.39	0.31	0.20
Silt loam	1.9	**2.0**	2.4	**0.50**	0.70	0.90	0.51	0.39	0.31	0.20
Sandy clay loam	1.7	**1.8**	2.1	**0.45**	0.63	0.81	0.39	0.31	0.24	0.16
Clay loam	1.7	**1.9**	2.4	**0.48**	0.67	0.86	0.31	0.24	0.20	0.12
Silty clay loam	1.6	**1.9**	2.3	**0.48**	0.67	0.86	0.31	0.24	0.20	0.12
Clay	1.5	**1.8**	2.2	**0.45**	0.63	0.81	0.20	0.16	0.12	0.08

** **Net** is for an Irrigation Efficiency, **IE,** of 1.0 (100% of the irrigation water that is pumped/supplied ends up available to the crop/to match ET). To get the **Gross** (the actual amount that must be pumped/supplied), divide the Net values by the actual IE of the irrigation system.

*** The values in the 25% column are the depths of water that must be pumped to equal/replace the readily plant available water when IE is 1.0; otherwise divide by the actual IE: or if IE is near 0.7, use the values in the 35% column; and if IE is about 0.55, use those in the 45% column.

**** Where plants are small and for bare or crusted soils, reduce these rates by at least one half.

The length/time of an irrigation event governs the amount of water applied. There's a fine line between applying too much and just the right amount of water. Over and under irrigating definitely can hurt yield and quality, and increases waste and cost of production. Applying too little water per irrigation event can result in an excessive number of events necessary to keep the crop from stressing. Applying too much water per event decreases irrigation efficiency because the excess water ends-up wasted, outside/below the crop's active/current root-zone.

Pumping rate

In some cases the pumping/supply rates might not be adequate to meet the entire crop's peak water demand. Then during the peak demand period, one should *consider* using the available capacity to fully/adequately irrigate as much of the planting as possible and sacrificing the remaining, versus practicing deficit irrigation on the entire planting.

The *minimum* pumping/supply rate, $Q_{m,}$ for an irrigation system to meet the peak/maximum water need, ET_p, of a crop [which may occur during the crop's critical period of water need (Table 1)] is:

$$\boxed{Q_m = \frac{}{}}$$

where

Q_m = the *minimum* system capacity, gpm
A = the area irrigated by the system, ft²
ET_p = the peak evapotranspiration, in/day
t= a decimal representing the portion of time that the system is irrigating/operating
IE = a decimal representing the irrigation efficiency
k = (7.48 gal/ft^3) **/** [(1440 min/day) X (12 in/ft)] = 4.33 x10^{-4}

If A is acres rather than square feet, the value of k is [(4.33 x10-4) X (43560 ft2/ac)] = 18.86.

As a "rule-of-thumb" for crops grown in the humid South, irrigation systems should have the ability:

- to apply at least 0.3 in/day [= 2.1 in/wk = 57,000 gal/wk/ac = 8146 gal/day/ac = 187 gal per day per 1000 ft^2 = 5.7 gpm/ac continuously (*24/7)* = estimated maximum/peak ET] and
- to apply the water in several/split/frequent applications (depending on the ability of the soil to hold/release water).

This 0.3 in/day "rule-of-thumb" value assumes that the irrigation system has an Irrigation Efficiency, **IE**, of 1.0; i.e., 100% of the irrigation/pumped water ends-up available to the crop – to match/replace ET. Irrigation efficiency is the portion of irrigation water that ends-up in the crop's root-zone area and is accessible-by/available-to the plants. It accounts for all losses in getting the water to where it is available to the crop (i.e., for water evaporated during irrigation, for water not being applied uniformly to the crop's root-zone, for water applied outside of the crop's root-zone, and for water moving from the crop's root-zone via translocation, or runoff and deep percolation). For most irrigation systems, the water losses during conveyance from the source to the emitting devices are negligible.

Growers shouldn't assume 100% efficiency when they irrigate. For the better planned/designed, maintained, and operated *drip/micro* irrigation systems, the in-field IE might be as high as 0.9. For *sprinkler* and *surface* irrigation systems, the in-field IE is usually lower than 0.8. In practice the "rule-of-thumb" application rate of 0.3 in/day based on an IE of 1.0 must be increased by dividing it by the actual IE. For example, if an irrigation system has an IE of 0.8 (80% of the pumped water ends up accessible to the crop), the pumping/irrigation rate would need to be [(0.3 in/day) / (0.8)] = 0.375 in/day; or 7.1 gpm/ac when irrigating continuously (*24/7)*, and 21 gpm/ac when irrigating only 8 h/day (i.e., when t = 0.33).

Also, the 0.3 in/day "rule-of-thumb" assumes that ET occurs from the entire *crop area*. But, if the crop is *drip/micro* irrigated and has less than a full plant canopy (e.g., because of wide row/bed spacings), the area that contributes to ET is often less than the entire crop area. For example, if a drip/micro irrigated crop has a partial canopy that limits ET to only 70% of that for a full canopy, the minimum pumping/irrigation rates based on the entire crop area is reduced by 30%; e.g., a 7.1 gpm/ac ET rate under full canopy would require a pumping/irrigation rate of only [(7.1 gpm) X (0.7)] = 5.0 gpm/ac based on the entire crop area. This is not the case with other types of irrigation (e.g., sprinkler) because the water applied to the non-canopy area beyond the rows/beds is not available to the crop/plants; it is fully wasted, usually to deep percolation.

Frequency of irrigation

More than one irrigation event per day may be needed to maintain ideal soil moisture. This is particularly true when vegetables (and other succulent crops) are grown in soils that have limited water holding capacity (such as sandy loams). Different soil types have different moisture holding capacities as indicated in Table 2. Soils with large amounts of silt, clay, and organic matter have greater water-holding capacities than sandy soils. Soils with greater water-holding capacities require less frequent irrigation than soils with lower water-holding capacities. When soils with greater water-holding capacities are irrigated less frequently, more water must be applied per irrigation event. The amount of water required is the same regardless of frequency of irrigation events.

NOTE: The values in Table 2 are for the **total** soil water that is available to plants per foot of soil depth; but ***only a portion of the total plant available is readily plant available***. Usually only about 25% (**¼**) of total available is readily available. And, *only when the soil moisture is maintained in the readily plant available range (near field capacity) will plant stress be minimal and adequately controlled*. For example, consider a vegetable crop growing in a fine sandy loam with a root-zone *area* covering the entire crop area. Then, for a root-zone *depth* of 18 inches, the crop has access to [(1.7 inches of total water per foot of soil, from Table 2) X (1.5 ft of soil depth) X (¼, for just the readily plant available portion of the total plant available water)] = 0.64 inches of readily plant available water. When the crop has an ET of 0.25 in/day, it will need to be irrigated ever (0.64/0.25) = 2.6 days, or more often. But, if the crop has a root-zone depth of only 6 inches, it will have access to only [(1.7 inches of total water per foot of soil) X (0.5 ft of soil) X (¼)] = 0.21-in of readily plant available water. Then, the crop will need to be irrigated more than once per day to meet its water demand of 0.25 in/day.

NOTE ALSO: If a crop can get water from only a portion of the crop area (usually the case with vegetables, especially those grown on raised beds using drip tape and plastic mulch), the amount of both total and readily plant available water is less by that portion. For the crop discussed above with the root-zone depth of 6 inches, if its root-zone area is only $^{1}/_{3}$ of the crop area, only an equivalent of [(0.21 inches) X ($^{1}/_{3}$)] = 0.07 inches of water is readily plant available to meet the demand of 0.25 in/day, necessitating 4 or more irrigation events per day. And if the root-zone depth is 18 inches, the readily plant available water is [(0.64 inches) X ($^{1}/_{3}$)] = 0.21-in, meaning that the frequency of irrigation events would need to be more than once per day.

The point is: Frequent irrigation events are necessary to adequately control plant stress (maintain ideal soil moisture), especially during periods of peak water need.

Soil moisture monitoring

Good vegetable production can be obtained by basing irrigation scheduling on soil moisture content alone (as measured by science-based instruments rather than by simply feeling the soil and/or observing plants; if you're sensing cues of water stress you have already lost yield and quality). Soil moisture monitoring should include data from both *in* root-zone and *below* root-zone. The *in* root-zone data is needed to determine how readily available the soil moisture is to plants and when to apply more water. The *below* root- zone data reveals if too much water has been added, and lost/wasted (e.g., to deep percolation).

Figure 1 - Field Station automatically measuring and transmitting tensiometric soil moisture and other soil indices at various depths.

If both the amount and the availability of the soil moisture at all locations in the crop area are the same and if the irrigation scheduling scheme is the same for all zones, monitoring the soil moisture status at just one site is adequate. Otherwise multiple sampling sites should be established so that data is collected where soil moisture and/or irrigation schemes differ.

Among the instruments available to measure soil moisture, tensiometers and electrical resistance-based sensors are most often used in crop production. These sense the ease/difficulty of removing water from soil, which is a measure of the amount of their own energy that the plants have to expend/use to get water. Data from tensiometers and electrical resistance-based sensors can be read manually or collected automatically and transmitted electronically (Figure 1). Detail information about these instruments, how they are used, and how to use the information they provide is readily available from many sources (e.g., instrument manufacturers, irrigation dealers, and University Extension personnel). [When possible, irrigation events should be scheduled to keep the gauge readings on tensiometers between about 5 and 20 (i.e., 5 to 20 centibars tension, or negative pressure); begin irrigating before the crop has

Figure 2 - Field Station continuously measuring and transmitting volumetric soil moisture and salinity (at various depths), weather (in and out of canopy), and irrigation system pressure (indicating when irrigation is occurring).

to use too much of its own energy to extract water (before the soil moisture tension exceeds 20 centibars) and stop before too much water has been added (before the tension will drop below 5 centibars); at and below 0 centibars the soil is saturated.]

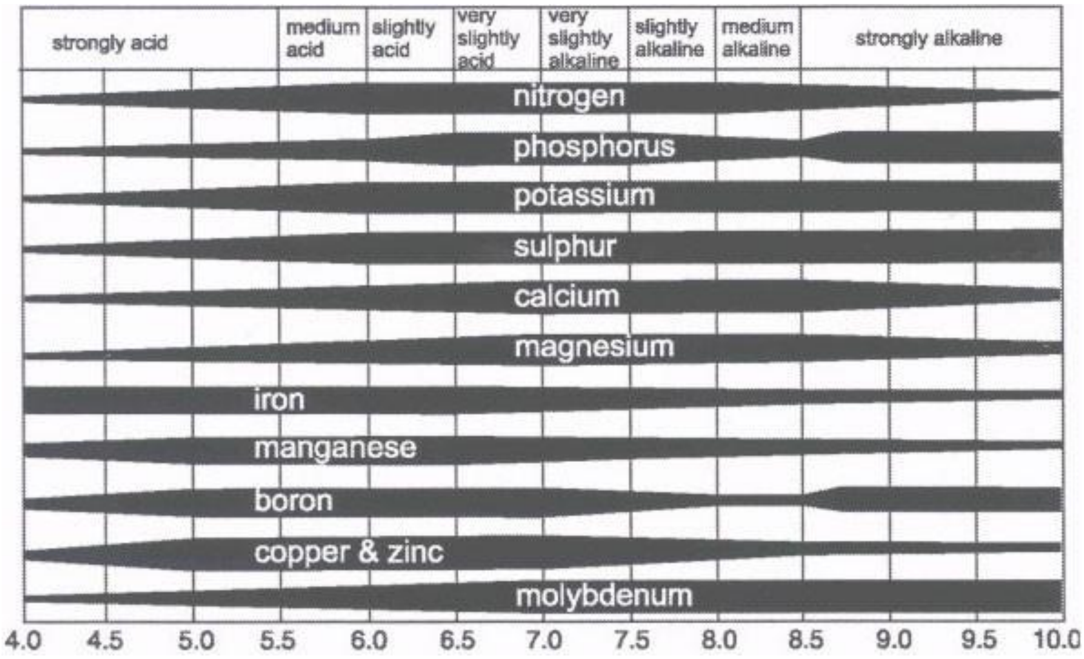
Irrigation scheduling can be improved by augmenting soil moisture data with weather data such as solar radiation, wind speed and direction, rainfall, and in- and above-canopy temperature and humidity (Figure 2). Weather data helps predict how fast the crop is using water and may give early indications of whether irrigation events should be delayed, omitted, or lengthened/shortened. Monitoring salinity and/or electrical conductivity can reveal additional information on where the irrigation water, fertilizers, etc., ends-up in the soil profile, and if they are available to the crop or wasted.

Fertigation

Applying plant nutrients/fertilizers and other agriculture chemicals through an irrigation system can be very efficient, economical, and timely. Starter and finisher fertilizer blends, and calcium and potassium nitrate are commonly applied via fertigation. Plants can be "spoon fed" just what they need, just when they need it, and with little cost of application and hardly any waste and pollution. In high rainfall areas/times, it is not uncommon to fertigate even when the crop does not necessarily need to be irrigated.

But before doing a fertilization program for a crop, the soil pH should be adjusted to the optimum value for growing that crop (typically, 6.0-7.5). Soil pH levels that are too high or too low can have a significant effect on yield and quality due to reduced nutrient availability (Table 3) and microbial activity. If a liming material is needed to increase the soil pH, it should be applied and incorporated to a depth of 5 to 6 inches into the soil as far ahead of planting as practical.

Table 3. Availability of Plant Nutrients vs. Soil pH



Since phosphorous is relatively non-mobile in soil, most of it probably should be applied pre-planting/pre-mulching. Additionally, 20 to 40% of the crop's nitrogen and potassium, and some micronutrients are generally applied pre-mulching/pre-planting. Apply pre-plant/pre-mulch fertilizer only into the root-zone area of the crop or the area that will be covered by the mulch, rather than broadcasting it over the entire crop area. The remainder of the crop's nutrient needs can be applied through the irrigation system. However in drip/micro systems, due to the small emitter passageways, only inject liquid or fully water-soluble fertilizers that are free of contaminants and that will not combine with other things in the water to form precipitates. Do a "jar test" before injecting (i.e., mix the water and fertilizer to see if the mixture forms a precipitate after it sits for about 6 hours).

The type, amount, and timing of nutrients to apply through an irrigation system depend on the crop's growth stage. In general, the type varies as the plant passes from its vegetative stages to its reproductive/fruiting stages, and smaller amounts of nutrients are needed early in the plant's growth, with peak demand occurring during the critical periods of crop growth (Table 1). The frequency of nutrient application is most influenced by the soil's nutrient holding capability (i.e., its cation exchange capacity). Clay soils have a high nutrient holding capacity and might respond adequately to bi-weekly nutrient applications through an irrigation system while a sandy soil with low nutrient holding capacity might respond best to a weekly or more frequent fertigation program.

Types of irrigation systems for vegetables

All *types* of irrigation systems [i.e., drip/micro, sprinkler/overhead, surface/gravity, and subirrigation (based on water table control)] can be used to produce vegetables. But the need to keep the soil moisture for vegetables in the *readily* plant available range (necessitating frequent irrigation events during periods of high ET) often limits the choices to either drip/micro or sprinkler, and requires that the systems be either (1) *solid-set* (i.e., capable of irrigating the entire production area without having to move components), or (2) *mechanical-move* machines that can be operated to irrigate the crop often.

Overhead/Sprinkler Irrigation

Sprinkler irrigation systems utilize a piping network to deliver pressurized water to application devices (e.g., sprinklers with nozzles) that discharge/spray the water into the air to fall as artificial rain/precipitation. Complete systems include pumps, chemical injectors, delivery and lateral piping/hose, control valves, and monitoring equipment including pressure gauges, flow meters, and soil moisture status indicators such as tensiometers. Sprinkler systems are either stationary or continuously moving, depending on whether the laterals (and sprinkler location) are stationary or move while water is being applied.

All sites and crops can be irrigated with some type of sprinkler system when due consideration is given to topography, soil, and crop peculiarities. In general, sprinkler irrigation can be used on any site that can be farmed. It is applicable to soils that are too shallow to permit surface forming (e.g., land leveling) and/or too variable for efficient surface irrigation. Even when other types of irrigation are the primary irrigation method, sprinkler systems are sometimes added for special purposes (e.g., to make light, frequent applications to germinate seed, to incorporate herbicides, for frost/freeze protection, for cooling, and to leach salts).

Labor requirements for sprinkler systems vary depending on the degree of automation and mechanization of the systems. Hand-move systems require the least degree of skill, but the greatest amount of labor. Center pivot and other mechanical-move systems require considerable operation and maintenance skills, but the overall amount of labor needed is low.

The major limiting factor for using sprinkler irrigation arrives from wetting all or much of the surfaces of the soil and crop. In practice this usually means that irrigation events are scheduled too infrequently to keep crops from undergoing significant/detrimental stress, especially on soils with low water holding capacity. Furthermore, wet soils can interfere with performing timely cultural practices. Evaporation can be large and agricultural chemicals can be removed. Wet foliage can intensify disease pressure. Crops may experience foliar damage by physical and/or chemical means when sprinkled. Some waters leave residues on plants that may reduce photosynthesis, growth, and/or marketability.

Another limitation relates to the relatively high energy usage. Energy consumption depends on the pressure requirements and the irrigation efficiency (low efficiency means more water must be pumped/applied), both of which vary considerably between types of sprinkler systems. At the extremes, a low energy precision application (LEPA) center pivot system may require little more than 15 psi and have an irrigation efficiency greater than 0.9. A hose traveler system may require an inlet pressure of as much as 90 psi to obtain a nozzle pressure of 50 psi and have an irrigation efficiency of only 0.6, meaning that [(1.00) / (0.60)] = 1.67 times the amount of water needed by the crop must be pumped, and at a very high pressure.

Critical to how well a sprinkler system performs are the sprinkler spacing, the pressure at the nozzle, the pressure variation between nozzles, the wind conditions, and how vertical the sprinklers are during operation. When sprinkling most crops, both droplet size and application/precipitation rate are very important, and these are governed by pressure at the sprinkler nozzle. Large droplets resulting from low pressure can cause damage to young plants and can contribute to soil compacting and crusting. Excessive pressure results in fine droplets and can lead to poor and distorted distribution and high evaporation, especially under windy conditions. Except for sprinklers fitted with flow regulated nozzles (orifice size and/or configuration changes with pressure changes to maintain a constant discharge rate), both the discharge rate and the distribution pattern of a sprinkler vary with pressure. Pressure regulators can be installed at each sprinkler to limit these variations; they are especially needed on fields/zones with varying elevations and on systems that operate at lower pressures.

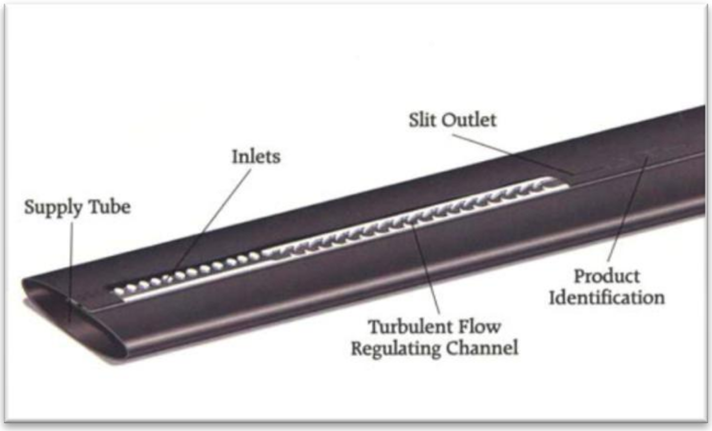
In general, maximum irrigation/application/precipitation rates should not exceed the soil infiltration rates. A soil's infiltration rate decreases as water is applied and as the surface seals. The rate of this decrease is faster at first and usually continues for several hours. Table 2 gives maximum sprinkler irrigation application/perception rates for various soil textures and slopes. High precipitation rates can result in the applied water ending up where it can't be used by the crop because of translocation. This not only contributes to low irrigation efficiency (more pumping) but also to erosion, fertilizer/chemical loss, and pollution. A variety of products and ways are available to minimize translocation including (1) tillage methods that leave small basins that retain the water at the point of application until it infiltrates, and (2) smaller sprinklers/heads, which generally result in lower precipitation rates.

Also, when sprinkler irrigation is used in areas that have relatively large boundaries (e.g., small patches and long, narrow fields), the water falling outside the crop area is usually large. This contributes to low irrigation efficiency values, meaning that an alternate type of irrigation system (e.g., drip tape) should be considered.

Drip tape irrigation

Drip tape systems are a type of solid-set irrigation; i.e., enough material is placed in the field so that it is not necessary to move components to irrigate the entire site (valves direct water between zones as needed). They are characterized by relatively low operating pressure, slow application/precipitation rate, and precise water placement. Complete systems include pumps, filters, chemical injectors, main and submain pipe/hose, control valves, and monitoring equipment including pressure gauges, flow meters, and soil moisture status indicators such as tensiometers. They use drip tape as laterals to deliver water (and fertilizers, etc.) uniformly, on or below the soil surface, along the crop rows/beds.

Drip tape is a relatively inexpensive, thin walled, collapsible/flat, plastic (polyethylene) tube with closely spaced, discrete, built-in water outlets/emitters; the tube rounds out under pressure. The emitters in today's drip tape are relatively clog-free thanks to large, torturous passage-ways and the scouring action of the water as it flows through the emitters with turbulences, rather than as laminar/smooth flow. Sometimes drip tape is retrieved for reuse, but it is most often removed and discarded at the end of cropping. In vegetable production, it is seldom installed as a permanent subsurface drip system (SDI); it is often placed just below the soil surface, in raised beds, and under plastic mulch.



Drip tape is available in several wall thicknesses from 4 to 15 mil (1 mil = $^{1}/_{1000}$-inch); the greater the mil, the more abuse the drip tape will withstand. The thinnest drip tape recommended for vegetables in the Southeast is 8 mil. The recommended inlet pressure to drip tape is usually about 10 psi. Most/common drip tape has a diameter of 0.62-inch (16 mm), but other diameters up to 1.4-inch (35 mm) are available for longer runs (to limit pressure loss due to friction and thereby maintain uniform discharge along the length/runs of the drip tape). Some drip tape is nearly fully pressure compensating, but most is not. For most, doubling the pressure increases the discharge rate by 1.5.

Drip tape is available with different distances between outlets, and with different outlet discharge rates. Close outlet spacings and slow discharge rates are recommended for course texture soils such as sands. Slow discharge rates and wider spacings are recommended for tight texture soils such as clays. A low flow, 5/8-in diameter drip tape with outlets 8 inches apart has a discharge rate of $^1/_3$ gpm per 100 ft at 8 psi, and will give discharge uniformities of greater than 90% *on level runs* up to 580 feet in length. Under the same conditions, if the drip tape were ultra low flow ($^1/_6$ gpm per 100 ft), the length of run could be almost 800 feet. But if it were high flow ($^2/_3$ gpm per 100 ft), the length of run would need to be under 400 ft.

Drip tape systems allow for water to be applied frequently, even more often than daily, to maintain favorable soil moisture conditions; even so, field operations can continue uninterrupted. They operate without necessarily wetting the soil surface and foliage, thereby limiting evaporative losses, disease pressure, and the amount of pest control needed. The areas between rows/beds remain dry, reducing weed growth and the loss of water and other resources. Hardly any fertilizers and other agriculture chemicals that are applied through drip tape systems need be wasted. Additionally, they conserve energy by operating at low pressure and high irrigation efficiency.

Still, drip irrigated crops can require 10% or more water than sprinkler or surface irrigated crops because of increased plant vigor, larger canopies, and heavier fruit setting.

Length of drip tape irrigation events

In most drip tape systems, water is applied to only a portion of the total crop area, and generally only to a portion of the root-zone area once the plants are grown/mature. This limits the reservoir of soil water available to the crop and poses a real potential to stress the plants, especially during the crop's peak and/or critical periods of water need. This necessitates frequent and precisely timed irrigation events and begs-for complete automation of the system.

The length/time of an irrigation event governs the amount of water applied. There's a fine line between applying too much and just the right amount of water. Over and under irrigating definitely can hurt yield and quality, and increases waste and cost of production. Applying too little water per event can result in an excessive number of irrigation events necessary to keep the crop from stressing. Applying too much water per event decreases irrigation efficiency because the excess water ends-up wasted, outside/below the crop's active/current root-zone.

Because drip tape systems usually apply water to only a portion of the total crop area, calculating the *optimum* length of time per irrigation event can be challenging. Table 4 gives the length of time required to apply 1-inch of water to the entire crop area (whether or not the water is actually applied to the entire crop area or just some portion, such as two-thirds of the total). The use of the values in Table 4 requires that the drip tape be operated at the pressure required (usually 8 psi at the emitters) to give the discharge rate indicated, and that the spacing between tapes be as shown. Note that the values (hours) assume prefect irrigation efficiency, i.e., IE = 1.0. To get the times of operation to apply 1-in that is *available* to the crop, increase the values (hours) in Table 4 by dividing them by the system IE. For example, with an IE = 0.83, the time required to apply 1-in that is *available* to the crop, using drip tape with a discharge rate of 0.34 gph/100 ft and spaced 5 ft apart, is [(15.3 hours from Table 4) / (0.83 for 83% efficiency)] = 18.4 hours.

Table 4. Hours Required to Apply 1-inch of Water VS. Drip Tape Spacing and Discharge Rate

Drip Tape Discharge Rate		Spacing between Drip Tapes (Feet)				
gph/100 ft.	***gpm/100 ft.***	***4***	***5***	***6***	***8***	***10***
11.4	0.19	21.9	27.3	32.8	43.7	54.7
13.2	0.22	18.9	23.6	28.3	37.8	47.2
20.4	0.34	12.2	15.3	18.3	24.4	30.6
27.0	0.45	9.2	11.5	13.9	18.5	23.1
40.2	0.67	6.2	7.8	9.3	12.4	15.5
80.4	1.34	3.1	3.9	4.7	6.2	7.8

To get the time required to apply some depth other than 1-inch, just multiply the times given Table 4 by the depth needed. For example, for a drip tape system with an IE = 1.0, and with 0.34 gph/100 ft drip tape spaced 5 ft apart, the time required to apply 0.72-in (whether or not the water is actually applied to the total area or just to some portion of the total, such as one-half of the root-zone area), would be [(15.3 hours) X (0.72)] = 11 hours. And, if the system has an IE = 0.83 (rather than 1.0), the time needed to apply 0.72-in that is *available* to the crop would be [(11 h) **/** (0.83)] = 13.3 hours.

When a crop is in its peak and/or critical period for water need (Table 1), its root-zone volume may equal or be larger than the soil volume watered by a drip tape system. Then if the irrigation event is not so long as to cause deep percolation (beyond the root-zone), a fair assumption is that almost all the water applied by the drip tape system ends up in the crop's root-zone and is accessible-by/available-to the crop. Any irrigation water not available to the plants would be due to unequal discharge rates from/along the drip tape, which is normally planned/designed to be less than 10%, meaning that the system could have an IE larger than 0.9.

The general relationship to determine the *maximum* length of time per drip tape irrigation event (i.e., the time required to apply the amount of water that the soil volume receiving the water can hold as *readily* plant available) is:

$$\boxed{\frac{Maximum\ volume\ of\ water\ to\ apply\ per\ irrigation\ event}{(Drip\ tape\ discharge\ rate)(Irrigation\ efficiency)}}$$

One form of this relationship is:

The information needed for this relationship is:

1) The width and depth of the strip of soil along the length of the drip tape that is to receive/hold the water; e.g., a 30-inch wide by 10-inch deep area,

2) The ability of the soil to hold and *readily* release water; e.g., a loam soil holds 1.9 inches of total plant available water per foot depth of soil (Table 2) but only about ¼ of this is readily plant available; thus the maximum amount of water to apply per irrigation event to this soil is [(1.9 in) / (4)] = 0.48-inch of water per foot of soil depth,

3) The discharge rate of the drip tape; e.g. 0.34 gpm per 100 ft,

4) The irrigation efficiency, IE, which can be high, e.g., 0.9 and,

5) Conversion for units, e.g., 231 in^3/gal.

Using the example/sample values given above, the maximum length of time per irrigation event would be:

Another form of this relationship (when the area to receive/hold the water is some portion of the entire crop area and the drip tape spacing is known) is:

Using the example/sample values above, except changing item (1) to: $^1/_3$ of the entire crop area is to be watered by drip tapes spaced 6 feet apart (i.e., a 24-inch wide strip per drip tape) to a depth of 10 inches, the maximum length of time per irrigation event would be:

$$\boxed{\frac{(24in)(10in)\left(0.48\,\dfrac{in}{ft}\right)}{\dfrac{(0.34gpm)}{(100ft)}(0.9)\left(231\,\dfrac{in^3}{gal}\right)} = 163\ min, or\ 2.7\ hours}$$

Problems inherent to drip tape irrigation

While drip tape irrigation systems are wonderful for precisely delivering water and chemicals directly to plants, they are subject to being damaged by insects, rodents, and laborers, and clogged by poor quality water. They must be routinely monitored and maintained for best results. Pressure regulation and filtration are required; pressure gauges and flow meters are a must for monitoring how well/efficient a system is performing, and they are useful in detecting leaks and emitter clogging.

The small water passageways of drip tape emitting devices present a challenge when combined with poor water quality. The cross sectional area of the pathway of a typical drip tape emitter is only 0.0004 in^2 (0.02 in x 0.02 in). Clogging results from physical (grit, sand), organic (bacteria, algae), and/or chemical (iron, manganese, calcium) water constituents; frequently it is caused by a combination of more than one of these. Irrigation water containing concentrations of iron greater than about 0.5 ppm can lead to drip tape emitter clogging problems. Even with good filtration, some organics (e.g., algae and algae parts) may pass through and cause clogging. Furthermore, microorganisms (e.g., bacteria) can grow inside micro irrigation systems, forming biological slimes that can clog the emission devices.

While the sensitivity of emission devices to clogging varies with type and design, all can become clogged; likewise, all can be operated without becoming clogged. Controlling emitter clogging requires (1) identification of the cause(s) and (2) application of some common, practical operation and/or treatment procedures.

All micro irrigation systems should include a filter. Even if the water source is "clean", it should include at least a screen or disc filter. Sand media filtration, the “fail-safe” filtration method, can be used on clean water sources, and it is strongly recommended for ***removing*** containments from "dirty" waters such as *most* surface waters.

Beyond filtration, flushing the system, especially at the far ends of the drip tape laterals, is usually the most important practice to control clogging. The flow velocity from the flushing opening should be greater than 1 foot per second. Automated flushing is recommended.

Drip tape irrigation systems that use waters that contain organics may benefit from injection of an oxidizing agent such as chlorine, either continuously and/or otherwise. Waters (mainly well waters) that contain contaminates that precipitate-out (e.g., iron and calcium) may require chemical treatment such as continuous or occasional injection of sequestering agents, oxidizing chemicals, and/or acids.

Chlorine is the most common material injected into drip tape systems to control clogging. It is available as a gas, liquid, and solid. Chlorine gas is low cost but extremely dangerous, and great caution should be exercised when using it. Solid chlorine is available as granules or tablets containing 65% to 70% calcium hypochlorite; the calcium can react/combine with contaminants found in some irrigation waters to form precipitates which could clog emitters. Liquid chlorine is the easiest and often the safest form to use in drip tape systems; it is available in many forms, including sodium hypochlorite (household bleach). The sodium ion is harmful to certain plants; e.g., blueberries. Common stock solutions of sodium hypochlorite have concentrations of 5.25%, 10%, or 15% ***free*,** or residual, chlorine. If stored improperly (e.g., in sunlight), sodium hypochlorite can lose part or all of its ability to oxidize; i.e., its free chlorine.

Free chlorine can be tested for using an inexpensive diethyl-phenylene-diamine (DPD) test kit. A swimming pool test kit can be used, but only if it measures only free chlorine. Many pool test kits only measure total (free and combined) chlorine.

Treatment of water with chlorine should be done **before** significant clogging occurs. Chlorine oxidizes most effectively at pH 6.0 to 7.5. Thus, the required rate and/or frequency of chlorine injection are not only dependent on the amount of organics, microorganisms, and/or iron present in the water, but also on the pH of the water. Some expensive, commercial chlorination equipment actually inject buffers to maintain optimum pH.

Thorough mixing of the chlorine in the water is essential. Flow through an elbow is usually adequate to assure this. Chlorine injectors should be installed a distance upstream from/before filters.

Use one of the following schemes as a starting point for treating water containing organics:

- If the organic load is high, continuously inject 5 to 10 ppm of free chlorine; the presence of 1 ppm of **free** chlorine at the end of the furthest lateral will assure that enough chlorine is being injected.
- If the organic load is medium, inject 10 to 20 ppm of free chlorine during the last 30 minutes of each irrigation cycle/event.
- If the organic load is low, inject 50 ppm of free chlorine during the last 30 minutes of an irrigation event two times per month of irrigation.
- For each month of irrigation, super-chlorinate long enough to fill the entire system with 200 to 500 ppm of free chlorine; then wait 24 hours, and open and flush the laterals.

The injection rates of stock solutions of chlorine to get various concentrations of free chlorine in irrigation water can be calculated as follows:

$$\boxed{(Injection\ rate\ of\ stock\ solution, gph) = \frac{(Desired\ free\ chlorination\ level, ppm)(Irrigation\ flow\ rate, gpm)}{S}}$$

where:

S = 875 for a stock solution of 5.25% free chlorine,
S = 1667 for a stock solution of 10% free chlorine, and
S = 2500 for a stock solution of 15% free chlorine.

For example, to get a 4 ppm level in a 50 gpm system, the injection rate would be 0.23 gph when using a 5.25% solution, or 0.12 gph when using a 10% solution, or 0.08 gph when using a 15% solution.

The water that is associated with **iron** clogging of drip tape irrigation systems/emitters is taken directly from wells. In ground water, the iron is the soluble ferrous type. When this dissolved ferrous iron is oxidized (either directly with oxygen from the air or by a type of bacteria that "feeds" on iron) it becomes insoluble ferric iron; this oxidized form of iron can precipitate in time on surfaces as rust and/or combine with microorganisms growing in the drip tape system to form iron-laden, microbial-masses. These slimy masses usually combine with and trap/entangle other things/contaminants (e.g., soil particles) in the irrigation water and system components.

Treatment of water containing iron to control emitter clogging calls for injecting a sequestering agent or an oxidizing agent. Sequestering agents combine with the ferrous iron in water before it is oxidized, producing a soluble iron compound that can pass through drip tape emitters. Oxidizing agents, like chlorine and peracetic acid, not only oxidize the iron but also control biological growth and the formation of iron-laden, microbial-masses. In some cases, the oxidized ferric iron may still pass through the emitters without clogging them. In other cases, this insoluble iron is encouraged to precipitate/coagulate into large enough particles that can be removed from the system by filtration. Still, usually enough iron will pass through the filters to necessitate control of biological growth downstream of filters.

To treat for iron in irrigation water with chlorine, the chlorine must be injected continuously. As a starting point, inject 1 ppm of free chlorine for each ppm of iron. In most cases, 3 to 5 ppm of free chlorine is sufficient. A residue of 1 ppm of **free** chlorine at the end of the furthest lateral will assure that enough chlorine is being injected.

Important notes regarding the use of chlorine include:

- Use approved backflow control valves, low pressure drains, and interlocks to protect the water source.
- Only inject products that are approved for use in irrigation systems.
- Chlorine concentrations above 30 ppm may harm/kill some vegetable plants.
- Chlorine injection/treatment should take place upstream of filters.
- Old stock solutions of sodium hypochlorite may have lost part or all of their ability to oxidize.
- Chlorination increases pH.
- Chlorine is most effective in water that is slightly acidic.

Works Cited

Hoffman, G. J., R. G. Evans, M. E. Jensen, D. L. Martin, and R. L. Elliott (Editors). 2007. *Design and Operation of Farm Irrigation Systems*, 2nd ed.: ASAE/ASABE, St. Joseph, MI.

Kemble, J. M. (Senior Editor) Extension Horticulture, Auburn University, Auburn, AL. 2014 Southeastern U. S. Vegetable Crop HANDBOOK.

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