



for vegetable production.

Determining water requirement

Evapotranspiration. Environmental variables such as solar radiation, air temperature, relative humidity, and wind speed interact to influence the rate of water loss from plants and soil. Historically, the most common technique for integrating these environmental variables and estimating evapotranspiration (ET_o, the combined water loss from plants and soil) has been the Class A pan evaporimeter. This device is simply an open pan of water in which the depth of daily evaporation is measured. In California, however, we are fortunate to have the California Irrigation Management Information System (CIMIS), a network of computerized weather stations that measure the important environmental variables that govern water loss. From these measurements a daily ET_o value is calculated, which has been very useful in estimating actual crop water needs.

Crop growth stage. There are considerable differences in growth habit, rooting depth, sensitivity to water stress, etc. among vegetable crops. However, their water use characteristics are more similar than one might expect. By far, the most significant factor in determining water needs is crop growth stage. A convenient way to account for crop growth stage is to estimate, by sighting down the row, the percentage of the field surface covered by foliage (canopy). Calculation for crop water need is: ET_o (cumulative from last irrigation) x canopy spread (inches) divided by row width (inches). Until substantial foliage cover occurs, however, it is critical to back up this estimation procedure with a direct soil moisture measurement. One of the limitations of this way of calculating is it is difficult to get an estimate on very young plants.

System inefficiency. No drip system delivers equal amounts of water to all portions of a field. There is a natural tendency to irrigate based on the drier areas. Generally, an additional 10 to 15 percent should be factored in to cover system inefficiency. A more difficult problem is the inefficiency of buried drip systems to supply shallow-rooted crops such as celery or lettuce that may not be able to reach all the applied water. The problem can be minimized by: 1) using relatively flat beds to minimize drip tube depth, 2) forming tightly pressed beds to improve capillary water movement, and 3) irrigating often, using

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Drip Irrigation Improves N Efficiency

Trend in California is drip irrigation to improve water/N management and protect environment.

Summary: To realize benefits from drip irrigation systems requires careful management of both water and fertilizer inputs. Determination of both crop irrigation and nitrogen fertigation requirements is essential. Factors such as water loss rate, plant growth habits, system inefficiencies, nitrogen cycling, soil N availability, crop N needs, and irrigation water N content must be carefully monitored. The tendency to use excessive water and fertilizer in drip irrigation systems can be shortsighted and environmentally undesirable.

The use of drip (trickle) irrigation for vegetable production is rapidly increasing. By 1995, nearly 100,000 acres of vegetables were drip-irrigated in California. There are a number of factors driving this conversion to drip irrigation, most important among them:

- increased crop yield potential
- water conservation
- more efficient nutrient management.

To realize these benefits requires careful management of both water and fertilizer inputs. We'll cover some of the basics of drip irrigation and fertigation management

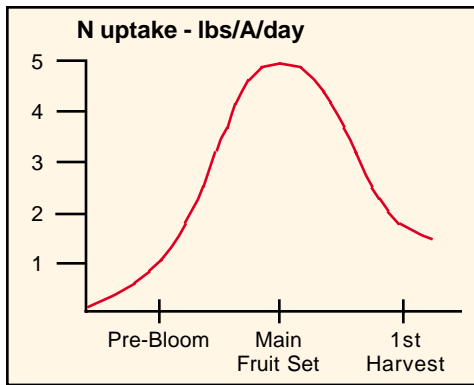


Figure 1. N uptake of tomato plants from pre-bloom through harvest, Hartz, University of California.

high-flow tape or tubing. Particular caution should be taken to see heavy soils stay moist.

Irrigation frequency. The use of two easy rules will help decide how often to irrigate: 1) deplete no more than 20 to 25 percent of available moisture in the most active root zone, and 2) limit individual applications to less than 0.5 inches.

Time vs volume. The only way to be sure you are applying the correct volume of water is by monitoring an accurate flow meter. Thinking in terms of duration or hours of run can lead to serious problems. Faulty equipment can skew the delivery rate of water considerably.

Over-irrigation. Although some degree of saturation is inevitable, it is important to minimize this stress to get the full advantages of drip irrigation. A tensiometer reading less than 10 cb generally indicates that saturation or near-saturation conditions

exist. Such monitoring will also help minimize leaching of nitrate below the crop root zone.

Determining N requirements

Uptake pattern. Vegetable crops differ widely in their nitrogen needs and in the pattern of uptake over the growing season. Fruiting crops such as tomatoes, peppers and melons require little N until flowering begins, then increase their N uptake, reaching a peak during fruit set and early fruit bulking period. Non-fruiting crops such as broccoli, celery and lettuce show slow N uptake through the first half of the season, with N need accelerating until just before harvest. Figures 1, 2 and 3 show typical uptake patterns for tomatoes, lettuce and peppers.

Soil N. Most soil N is tied up in complex forms in organic matter and is unavailable to the plant. The rate at which these complex forms are broken down into plant-available forms is constantly changing, controlled by a series of interactions of crop residues, soil microbes, soil moisture, and temperature. When crop residues are incorporated into the soil, they can contain substantial N. After incorporation, this residue is degraded over time by soil microbes, releasing inorganic nitrogen available for uptake by the next crop. This release of available nitrogen, called mineralization, occurs rapidly from the breakdown of fresh, high-nitrogen crop residues and more slowly from the older, more stable organic matter in the soil. The result is that succeeding crops can draw a substantial portion of the nitrogen they need, perhaps 50 percent or more, from

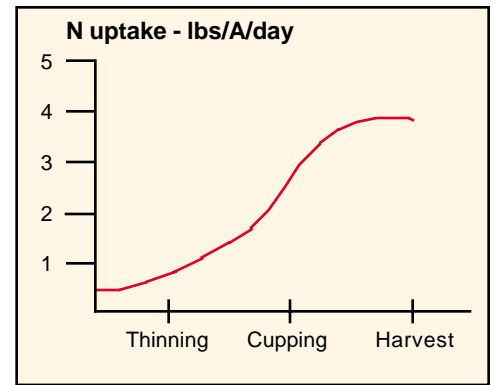


Figure 2. N uptake of lettuce plants from thinning through harvest, Hartz, University of California.

this pool of soil N. Ammonium and nitrate are the common forms of plant-available nitrogen. Most vegetable crops will use both forms, although most rapid growth is usually favored more by nitrate than by ammonium.

More extensive monitoring of soil nitrogen status is justified, since drip irrigation provides the ability to add nitrogen on demand. One form of measuring is the use of soil solution access tubes (SSAT). Clearly, using SSATs to determine N deficiency would not be appropriate. However they do provide a simple and inexpensive method for determining when soil N is clearly sufficient. Other methods of measurement are extraction of soil N in aluminum sulfate solution and a "quick test" procedure.

Application frequency. In sprinkler or furrow irrigated cultures, nitrogen applications are generally large and infrequent. Drip irrigation offers nearly limitless

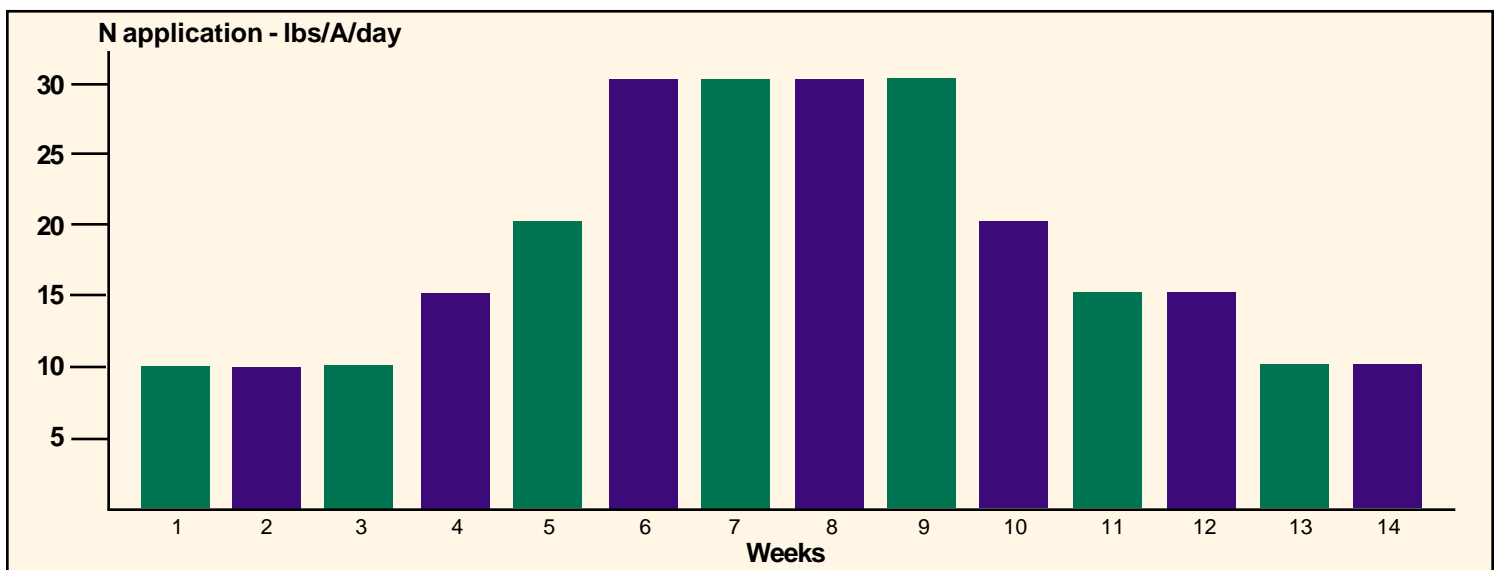


Figure 3. Pepper fertigation template over 14-week period, Hartz, University of California.

flexibility, allowing for daily N application if desired. The question of fertigation frequency has not been extensively researched, but most available information suggests that weekly additions are as effective as more frequent applications.

Crop N status. Conventional plant tissue analysis, in which tissue is dried, ground and chemically analyzed in a laboratory, is the most accurate way to determine crop N status. Through decades of experience, N sufficiency guidelines have been developed for most vegetable crops. Although not specifically developed for drip irrigation, these standards are still generally applicable. To get the most useful data, particular attention should be given to: 1) plant sampling technique, 2) determination of growth stage, and 3) handling and preparation of samples.

Fertility planning

Developing an efficient fertility plan involves three additional factors to be considered.

Estimating soil N. Residual ammonium and nitrate present in the soil should be estimated at the start of the season through preplant sampling. Estimate of how much N will be mineralized as the season progresses is difficult.

Crop development rate. Relative crop development rate (directly tied to temperature) should be accounted for so fertilizer additions can be planned on the basis of daily and weekly needs. Total crop N needs are relatively independent of environmental conditions.

Water N content. Nitrogen content of irrigation water should be determined where substantial amounts of nitrate (especially in well water) may be present. Some wells in the Salinas Valley and the eastern San Joaquin Valley contain more than 10 ppm. Formula for determining N content is: ppm of NO₃-N in water x 0.23 = pounds N per acre inch. For example, 18 inches of water with an NO₃-N content of 10 ppm would add 41.4 lbs/A of N over the cropping season.

Table 1 lists typical fertigation programs for some major vegetable crops. It should be used only as a guide, to be modified as individual circumstances require.

Table 1. Nitrogen fertigation requirements of vegetable crops under California conditions.

Crop	Growth State	Approx N requirement	
		Lbs/A/Week	
Broccoli	Early growth	5	15*
	Mid season	10	20
	Button formation	15	30
	Head development	10	20
Lettuce	Early growth	5	10
	Cupping	10	20
	Head filling	15	30
Pepper	Vegetative growth	5	10
	Early flowering/fruit set	15	30
	Fruit bulking	15	20
	First harvest	5	10
Tomato	Vegetative growth	5	10
	Early flowering/fruit set	15	20
	Fruit bulking	10	15
	First harvest	5	10
Cucumber	Vegetative growth	5	10
	Early flowering/fruit set	10	20
	Fruit bulking	10	15
	First harvest	5	10

*Higher values represent fertigation needs in low residual N soils and/or under high temperature (rapid growth) conditions.

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