

## **Drip Irrigation and Soil Fertility Management**

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The California vegetable industry is in the midst of an irrigation revolution. After many years of slow growth, drip irrigation has finally taken off. Use of drip in both the Central Valley and the coastal areas is now commonplace for the production of tomatoes, peppers, celery, lettuce and other vegetables. While growers recognize that drip irrigation requires radical changes in water management strategies, the impact of drip on soil fertility management is less obvious. The most frequently discussed effect of drip irrigation on fertilizer needs is the potential for reduced N leaching losses through greater irrigation efficiency. There are a number of other ways in which the conversion to drip irrigation may require adjustments to fertilizer strategies. The following discussion highlights some of those issues.

### **Buried vs. surface drip:**

There are two fundamentally different drip irrigation systems for vegetable crop production: 1) temporary surface system that are installed after crop establishment and removed before harvest, and 2) semi-permanent, buried systems that are left in place for multiple crops. Surface systems dominate in the coastal production areas, while buried systems are used almost exclusively in the Central Valley. Appropriate fertility management may be profoundly different with the two systems. With a temporary surface system, phosphorus application is typically done before system installation. The wetting is from the top down, pushing soluble nutrients toward the root zone. Because the system is temporary, and conventional tillage is practiced between crops, there is no significant 'mining' of nutrients from a particular region of the soil profile, nor are the effects of maintenance chemicals (acids, for example) spatially concentrated. By contrast, with a semi-permanent, buried system the surface 4-6 inches of soil may (depending on soil characteristics and system depth) often be too dry for active nutrient uptake. Evaporation from the soil surface may move soluble nutrients into this dry zone, beyond the reach of the crop. Since successive crops will draw the bulk of their nutrients from a confined area in the soil, the nutrient status of that area may change substantially over time. Acid-based products applied through the drip system can change pH of the wetted area, potentially affecting micronutrient availability.

### **Nitrogen management:**

The assumption that converting to drip irrigation will allow a grower to reduce N fertilizer use is an oversimplification. More efficient irrigation will reduce N leaching loss, but growers do not always achieve improved efficiency with drip irrigation; for example, a study of drip irrigation management in commercial celery fields showed that significant over-irrigation was common (Breschini and Hartz, 2002). Also, if yield expectations are higher with drip, additional N may be needed to accommodate the extra crop productivity. For example, if drip increases tomato yield by 6-8 tons/acre, the N in that additional fruit biomass could be as much as 30 lb/acre.

Another reason why drip irrigation may increase N fertilizer requirements is that the limited wetted zone reduces the amount of N mineralization from soil organic matter. This is an issue primarily with buried systems, because most N mineralization occurs in the tillage zone, which may remain dry during much of the season. Tillage practices that confine crop residues to the surface few inches of soil, and irrigating up a crop with the drip instead of sprinklers, will minimize the availability of N in those residues. Lastly, with buried systems, evaporation from the soil surface over time can deposit a considerable quantity of NO<sub>3</sub>-N in the dry surface soil; while this N may be recovered by a subsequent crop, it may be largely beyond the reach of the current crop. N fertigated early in the cropping cycle is particularly susceptible to this fate, since crop uptake is relatively slow until mid-season, and

evaporation is more rapid before the crop canopy shades the soil surface.

In summary, N requirements with drip irrigation will not be substantially lower than for *efficiently-managed* conventionally irrigation, and may in some cases be higher. Maximum N efficiency with drip can be achieved by a) efficiently controlling irrigation to minimize in-season leaching; b) sprinkling for stand establishment, thereby increasing the recovery of mineralized N; and c) timing N fertigation to match the crop uptake pattern.

### **P management:**

With appropriate safeguards, phosphorus can be applied through drip lines without chemical precipitation and emitter plugging. However, fertigating P may not be the most efficient approach to P fertilization. The degree to which fertigated P moves with the wetting front is affected by soil texture and pH. In fine-textured, alkaline soils fertigated P may not move more than a few inches from the emitters. Depending on the depth of the tape, that may not be close enough to efficiently supply young plants with limited root systems. Where buried drip systems are used, conventional banding of preplant P fertilizer may still be the most appropriate technique for growing direct-seeded crops. If transplants are used, the transplants can be charged with a shot of P fertilizer as they leave the nursery, or with a starter solution at transplanting, to support growth until roots can mine P applied through the drip tape.

In calculating P requirements for drip-irrigated culture it is important to understand that plant-available P generally declines with soil depth. It is not unusual for the top 6 inches of soil to have a bicarbonate P level 20-40% higher than that of the 6-18 inch depth. Since buried drip concentrates roots deeper in the soil than does conventional irrigation, soil sampling of the primary rooting zone may give a more accurate reflection of soil P status than would the conventional sampling of the top 6 or 12 inches.

### **K management:**

Drip irrigation provides an ideal vehicle for potassium application. Many California soils have a significant capacity to 'fix' applied K, and in these soils only a small percentage of K applied as a preplant or early sidedress is actually taken up by the crop. Fertigating K in small doses during a crop's rapid uptake phase delivers K directly to the concentrated root zone where uptake can occur before significant soil fixation. Partially offsetting this advantage is the fact that, as is the case with P, soil K declines with depth; soil sampling to determine K fertigation needs is most appropriately done by sampling the concentrated root zone, not the entire soil profile. Over several years of cropping the exchangeable K levels may decline in that confined root zone much more quickly than is typically the case in conventionally-irrigated fields, where crops draw K from the entire soil profile, and the K released from crop residue is more readily distributed into the rooting zone. If significant yield increase is expected from the conversion to drip, K application rates may need adjustment upward; for example, each ton of tomato fruit typically contains 4-6 lb K / acre.

### **Micronutrient management:**

Micronutrients are only occasionally an issue in California soils, regardless of the type of irrigation used. The concentration of plant-available micronutrients tend to decrease with soil depth, so fields with buried drip systems are marginally more likely to encounter deficiencies. Another potential problem with buried systems is that over time the use of fertilizers and acid-based maintenance chemicals can lower soil pH in the wetted zone, making some micronutrients less available. This is unlikely to be an issue in installations less than 5 years old, particularly in soils with a high buffering capacity.

**Nutrient monitoring:**

As in conventionally-irrigated fields, soil availability of P, K, and micronutrients are best assessed by annual preplant sampling. For buried drip systems the sample should be drawn from the primary rooting zone rather than from the entire soil profile. In-season soil NO<sub>3</sub>-N testing can be a valuable practice, particularly in the early portion of a cropping cycle, before the crop enters the rapid uptake phase. There is an on-farm 'quick test' method of NO<sub>3</sub>-N determination (Hartz et al., 2002) that is accurate enough to guide early-season fertigation decisions. A soil NO<sub>3</sub>-N concentration > 20 PPM is sufficient to support crop growth in the short term. Once the crop enters the rapid growth phase (when macronutrient uptake increases dramatically) the interpretation of soil NO<sub>3</sub>-N levels is more difficult since, in the confined rooting zone, crop uptake can reduce NO<sub>3</sub>-N concentrations quickly. At that point a schedule of N fertigation should be followed, based on assumed crop uptake rate; continued soil NO<sub>3</sub>-N testing can be used to help determine whether the fertigation rate is excessive.

The use of soil solution access tubes (also called suction lysimeters) for routine monitoring of macronutrient concentrations in soil solution have been advocated as a technique uniquely suited to drip-irrigated production. There are a number of problems with this technique that make it unreliable, the most important of which is the spatial variability of soil nutrient concentration. The area from which the lysimeter draws soil solution is limited, and the concentration of macronutrients (particularly NO<sub>3</sub>-N) is highly stratified in the root zone. Therefore, the solution from one tube may or may not accurately reflect the average of the root zone; to have confidence in this technique, combining samples from instruments in different areas of the field and different locations with respect to emitters would be needed, making this a laborious technique.

Similarly, petiole sap analysis has been touted as an ideal diagnostic for drip irrigation. While this approach has some merit, it has limitations as well. Foremost among these is accuracy. The common 'Cardy' meters used to measure NO<sub>3</sub>-N and K in petiole sap are subject to significant errors, due mostly to competing ion effects and fouling of the ion-selective membranes. Even if the meters are maintained properly, and calibrated correctly each day of use, the readings obtained should be viewed as approximations, essentially a 'sufficient/deficient' diagnostic. The measurement precision is simply not good enough to justify endless tweaking of the fertigation schedule. Conventional laboratory analysis will generally yield more accurate results, and it is the only way to get information on P and micronutrient levels in tissue. For an expanded discussion on the value and limitations of tissue analysis see Hartz (2003).

**Putting it all together:**

Conversion to drip irrigation should require only minimal adjustment of P and K fertility management. Determination of P and K requirements should be based primarily on preplant soil testing, with most P applied preplant as in conventionally-irrigated culture. Where K is required, fertigation is likely to be the most efficient approach. Particularly with fruiting crops like tomato, tissue K concentrations can drop rapidly when maximum growth rate is reached, so the K fertigation schedule should keep ahead of the curve. If substantial improvement in irrigation efficiency is achieved in the conversion to drip, a reduction in overall N use may be possible. The N fertigation program should be based on a general crop template that takes into account the changes in N uptake by growth stage; adjustments to this template (usually downward) can be made based on in-season soil NO<sub>3</sub>-N testing of the rooting zone. Tissue analysis should be viewed as a technique to confirm the sufficiency of the fertility plan, rather than the primary diagnostic to drive future fertigation. This is particularly true of petiole sap analysis, given the inherent variability of that measurement.

**References:**

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