Fertility Management of Processing Tomato

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Introduction

Processing tomato production has changed greatly over the last decade. Improvement in varieties continues to increase yields and fruit quality. Transplanting has become the norm for most growers. The rapid adoption of drip irrigation is transforming not only how water it applied, but how crop fertility is managed. In light of these changes it is worthwhile to reconsider fertilizer management practices, particularly for drip-irrigated culture.

Nutrient uptake patterns

Processing tomato crops exhibit a characteristic nutrient uptake pattern – slow through field establishment and early vegetative growth, accelerating during fruit set and fruit bulking, and slowing as the crop matures. Fig. 1 shows a typical nutrient uptake pattern for a 40 ton/acre crop.

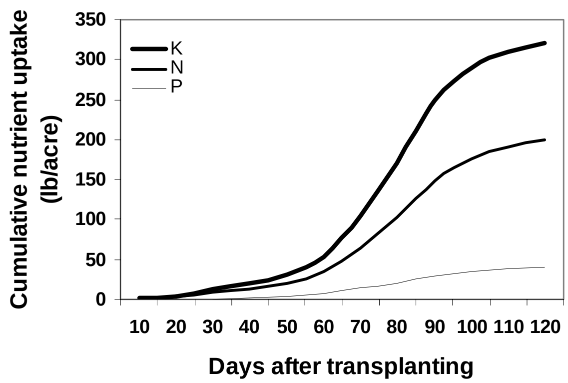

Fig. 1. Pattern of N / P/ K uptake in processing tomato.

At harvest the total macronutrient content of the whole crop (vines and fruit) averages approximately 200, 40, and 320 lb N, P, and K, respectively. A ton of fruit typically contains 3-4 lb N, 0.3-0.5 lb P, and 4-6 lb K.

Nitrogen management

Dozens of field trials in California have shown that conventionally-irrigated processing tomatoes generally require no more than 100-150 lb of fertilizer N/acre to achieve maximum yield; the remaining N comes from residual soil NO_3-N and soil organic N that is mineralized (made available) during the season. Since tomato is a moderately deep-rooted crop, NO_3-N leaching loss during the season is seldom large. In a study of 10 processing tomato fields, Krusekopf et al (2002) found that the residual soil NO_3-N prior to sidedressing averaged approximately 100 lb/acre in the top 2 feet, but varied among fields from 30-200 lb/acre. A fruit yield response to sidedress fertilization was observed in only 4 of the 10 fields. They concluded that soil sampling after crop establishment could help guide N fertility decisions, with fields with residual soil NO_3-N >15 PPM in the top foot requiring minimal N sidedressing to reach maximum yield potential.

If a grower has been efficiently managing water and N fertility with furrow irrigation, switching to drip irrigation is unlikely to reduce N fertilizer requirement significantly; growers who are able to dramatically cut back on N fertilizer application after switching to drip were probably over-fertilizing and/or over-irrigating their conventionally-irrigated fields. N fertilizer requirement may actually increase with drip, since higher yields are possible, and the mineralization of soil organic N may be limited because the surface soil stays dry. A reasonable N fertigation plan would be to apply a seasonal total of 100-180 lb N/acre, in multiple applications concentrated just before and during the rapid uptake phase of the crop. Light-textured soils, fields coming out of lightly fertilized crops (like wheat), fields with very heavy fruit set, and fields that have received significant winter rains (which may have leached residual soil NO_3-N) will in general require more N fertigation than fields of heavier soil texture that are coming out of a more heavily fertilized crop, or that receive little winter rain.

Phosphorus management

Few field trials on P fertilization of processing tomatoes have been conducted in recent years, so we have an incomplete picture of P fertilizer requirement for transplant, high-yield hybrid tomatoes. Based on research conducted in the 1970s and 1980s, the soil test threshold for crop yield response is between about 12-20 PPM P using the Olsen (bicarbonate) extraction procedure. Some early season vegetative growth response has been documented with P application in fields with higher soil test P, but that response has not generally carried through to produce a fruit yield response. It is probable that a 20 PPM soil test threshold for P fertilizer response is still an appropriate guideline for high-yield, transplanted tomatoes. Beyond soil test P level, the other main factor governing soil P availability is soil temperature; the lower the temperature, the less available the P. Using an anion membrane extraction technique, Johnstone et al. (2005) determined that, in California mineral soils, bioavailable P increased approximately 20% with each 10^oF increase in soil temperature. This means that, at the same soil test P level, P availability of a field planted in May would be > 20% higher than a field planted in March.

Although P fertilizers can be applied through drip irrigation (with proper safeguards to prevent chemical precipitation), fertigation may not be the best way to apply P. P supply is most limiting early in the season, when the soil is colder, and the limited root system of the crop reaches only a small volume of soil. This argues for applying most or all of the season's P requirement preplant, or at planting, regardless of irrigation technique. Placement of P close to the young plants maximizes availability. When P is applied through buried drip lines, the extent of movement away from the point of injection is governed by soil texture and pH; in alkaline soil of medium to heavy texture, fertigated P may move only a few inches from the tape, making it less available than if banded close to the plant row or applied in a transplant drench. Once the crop has developed a large, vigorous root system soil P is more readily accessible to the crop, and in-season P applications are not often necessary.

Potassium management

Potassium management is a complicated issue. K affects not only fruit yield, but also fruit color; the fruit disorder 'yellow shoulder' (YS), in which a ring of tissue surrounding the stem scar remains yellow after the fruit has ripened, is directly related to K nutrition. Soil K availability is also more complex than N or P, and therefore a more expansive discussion is warranted. The typical commercial lab evaluates soil K availability by extracting the soil with an ammonium acetate solution and measuring the cations removed from the soil exchange sites. The results are typically given either in parts per million (PPM) or in milliequivalents (meq)/100 g of soil (1 meq K/100 g = 390 PPM K). However, to get the most complete picture of relative K availability you also need to consider the relative abundance of K in relation to the other cations. The cation exchange of California soils is typically dominated by calcium, magnesium, potassium and sodium, collectively called the 'base exchange'. The higher the percentage of base exchange represented by K (on a milliequivalent basis), the more readily available K is for plant uptake; this is because there is competition among the various cations for uptake by plant roots. This is particularly true in the case of Mg, which tends to suppress K uptake. The higher the percentage of base exchange that is K, the more readily available K will be to the crop. Plants obtain K directly from soil solution and from cation exchange sites. Additionally, K trapped within silt and clay particles is in equilibrium with exchange site and soil solution K; as plants remove K, some of this trapped (or 'fixed') K is slowly brought into soil solution, available for plant uptake. When K fertilizer is applied to soil, the process works in the opposite direction; as the soil solution and the exchange sites are enriched by the fertilizer K, some of that K will become trapped in these 'fixation' sites. Much of this K movement into fixation sites occurs during soil drying cycles. Measured rates of fixation of applied K vary from < 10% to > 80% in Central Valley soils; K fixation rate is insignificant in very sandy soil and in soil with very high exchangeable K level, but it can be very high in heavy-textured soil with moderate to low exchangeable K.

Unlike nitrate, which is highly mobile, K moves very little in soil. The effective movement in water flow from the point of fertilizer application is typically no more than a few inches; the effective movement by diffusion is even less. This means that extensive rooting is required for the plant to successfully mine K from the entire soil profile, and that applied K must be placed close to a zone of intensive rooting to be maximally effective.

In light of the preceding discussion, and based on a series of 16 potassium fertilization trials conducted over the past decade (Hartz et al., 2000, 2005), the following recommendations can be made regarding K fertilization of processing tomatoes:

1) for conventionally-irrigated fields there is a high probability of increased yield with K fertilization in soil with exchangeable K < 130 PPM; yield improvement is increasingly less likely as soil exchangeable K increases above that level. Soils with low exchangeable K and low K intensity (< 2% of base exchange) are particularly likely to require fertilization. K fertilization may reduce, but will typically not eliminate, YS. Achieving significant reduction of YS may require more fertilization than is required for maximum yield; between 100-200 lb K_2O / acre should be sufficient to maximize yield in most circumstances, but even twice that amount may not reduce YS to acceptable levels. The effectiveness of preplant and sidedress K applications can be limited by soil fixation of applied K, and by the distance of the application from the zone of maximum root density. Management practices that encourage extensive rooting will increase crop K uptake. Conversely, practices that limit root development (causing soil compaction by working wet fields, for example) will aggravate K deficiency.

2) drip-irrigated fields may have a higher K requirement than if those same fields were furrow-irrigated. Yield expectations will be higher, and the extra fruit will require more K uptake. Secondly, because buried drip tends to reduce rooting in the top 6 inches of soil (the soil zone with the highest exchangeable K level), and to restrict rooting only to the area wetted by the drip

tape, the potential for K uptake from the soil is reduced. The good news is that applying K through the drip tape delivers K directly to the most concentrated root zone; also, because the soil around the tape is maintained moist, K fixation is limited. We have achieved significant tomato yield increases and fruit color improvements with K fertigation in fields with exchangeable K > 200 PPM. K fertigation has been most effective in increasing yield if it is applied from just before full bloom (when the early fruits are about 1 $^{1/2}$ inch in diameter, but before any gel development) until about 10% red fruit. Seasonal fertigation rates of 100-200 lb K_2O/acre should be sufficient in most cases. The form of K applied (sulfate or chloride) has not affected relative crop performance.

Micronutrients

Micronutrients are seldom limiting in Central Valley soils. Historically, soil Zn deficiency was relatively widespread, but addition of Zn in preplant fertilizers has enriched soil Zn supply to the point that Zn deficiency is now rare. While it is theoretically possible to encounter other micronutrient deficiencies, it is unlikely. The relative supply of Ca and Mg has implications for soil structure and water infiltration characteristics, but a nutrient deficiency of either element is unlikely. Blossom end rot of tomato fruit, often thought of as a Ca deficiency, is nearly always the result of transient water stress rather than lack of soil Ca; Ca moves within the plant in the transpirational stream, and even a temporary interruption of that stream prevents sufficient Ca from reaching rapidly growing tissues like young fruits.

Tissue testing

Plant tissue testing can help identify growth-limiting nutrient deficiency. Whole leaf total N/P/K analysis evaluates overall nutrient status, while petiole analysis provides a measure of unassimilated nutrients (NO_3-N, PO_4-P, and K) taken up but not yet incorporated into plant structures. Tissue analysis is most useful from early flowering through full bloom. Nutrient deficiency is rare before flowering (with the possible exception of P); after full bloom tissue nutrient concentration, particularly for K, is heavily influenced by fruit load; low tissue values may not reflect nutrient deficiency as much as nutrient export to the fruit.

A nutrient monitoring survey of >100 commercial fields was conducted in 1993-94 (Hartz et. al., 1998), and standards for whole leaf nutrient sufficiency were determined. (Table 1). These standards were determined by mathematically comparing the leaf nutrient concentrations of high-yield fields with those of low yield fields, and calculating an optimum range that encompassed the majority of nutritionally balanced, high-yield fields. These sufficiency levels are similar to prior UC guidelines for N and P, but considerably lower for K.

Table 1. Whole leaf macronutrient sufficiency guidelines.

	Sufficiency range by growth stage	
Nutrient	First flower	Full bloom
% N	4.6 - 5.2	3.5 - 4.5
% P	0.32 - 0.49	0.25 - 0.41
% K	2.2 - 3.5	1.6 - 3.1

Petiole analysis is also popular. Unfortunately, recent research on several vegetable crops, including processing tomatoes, has shown that petiole analysis is not a dependable measurement on which to base fertility management decisions. Factors such as temperature, solar radiation level, soil moisture availability, and even varietal differences can confound the relationship between soil nutrient availability and crop nutrient uptake, and affect the rate at which the plant incorporates the inorganic ions into organic compounds. *Very low* petiole nutrient concentrations are generally indicative of soil nutrient deficiency, but above 'obviously deficient' levels, these confounding factors render petiole nutrient concentration virtually meaningless. The historical petiole 'sufficiency' values developed by UC and other sources in the 1970s and 1980s were generally derived from only a few replicated fertilizer trials. Since only a narrow range of field environments were represented in these studies, the resulting values are not broadly applicable to the industry, and are generally higher than actually necessary for optimum growth. I do not recommend routine petiole analysis as a primary fertility management tool. Whole leaf total nutrient concentration, and soil testing, give more reliable information.

Given the preceding discussion it is clear that nutrient analysis of petiole sap is also a questionable technique. Beyond the limitation of petiole analysis per se, sap analysis adds additional variability because nutrient concentration varies with petiole water content. Furthermore, Cardy meters are less reliable than well-maintained laboratory equipment, and their use adds another layer of inaccuracy. Cardy meter analysis of petiole sap is a very rough diagnostic, and should only be used to distinguish obvious deficiency from probably sufficiency.

References

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