Soil Testing Options for High Tunnel Production

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High tunnel production systems offer several obvious advantages over open-field production. They also present unique nutrient management challenges. Primary advantages include greater control of nutrients and water, enhanced heat gain, additional growing degree days, and extension of the growing season both earlier and later in the year. With the advent of holding and harvesting late-planted crops through the winter (Coleman, 1999), many houses are being double or even triple-cropped each year. With no natural precipitation, all water must be supplied by irrigation – usually drip irrigation. Control over water inputs allows for better control of foliar diseases on susceptible crops such as tomatoes. Higher soil temperatures result in faster N and P mineralization rates from both chemical and non-chemical amendments.

There are also potential, and sometimes unanticipated, disadvantages to this system. Very high heat gain requires ventilation to avoid overheating. Higher temperatures in an enclosed environment – often in monoculture – can worsen insect pest problems. Greater biomass production creates greater nutrient demand from the soil. Soil nutrient levels that may have been adequate or only marginally deficient in an open-field system may result in a major deficiency in a high tunnel system.

One of the most common problems in a continuously covered high tunnel system is the buildup of nutrient salts over time. With no natural rainfall to flush excess salts and irrigation supplied only to satisfy crop requirement, yearly net movement of water is upward through the soil profile rather than downward. Evaporation from the soil surface plus transpiration demand by plants wicks water and dissolved nutrient salts to the surface where they can accumulate to levels sufficient to cause damage to crop plants. In this aspect, high tunnel soil management is very similar to irrigated desert production in the west and southwest. Many growers used to open-field production systems fail to realize this potential problem or take steps to remediate, such as uncovering to natural rainfall or otherwise flushing accumulated salts from the soil with high volumes of water. With minimal leaching or denitrification potential, nitrate carryover from one crop cycle to the next is another major difference compared to open-field production systems.

As requests for soil testing services for high tunnels increased at the University of Maine, it became apparent that routine field soil testing was inadequate to address many of the potential problems inherent in these production systems. Since high tunnel growers employ a wide range of soil amendments and management intensities, it became necessary to offer a range of testing options.

Appropriate Testing Systems

For new high tunnels, transitioning from an open-field to a covered production system, the most appropriate testing option is still a routine field soil test. Since greater productivity and greater nutrient demand is anticipated, all soil levels should be adjusted to the upper end of the optimum range for pH, organic matter, and all major and micronutrients according to existing soil fertility guidelines for open-field production. Even marginal nutrient levels should be amended to avoid potential deficiencies under high biomass production demands.

After the first cropping year, the potential for nutrient salt buildup and nitrate carryover should be addressed. Our first enhanced testing package called the Basic High Tunnel package is a traditional field soil test plus total water-soluble salts (by electrical conductivity or EC) plus a direct measurement of available nitrogen (NO_3-N and NH_4-N). This package has worked very well for the majority of our high tunnel growers. As with any traditional soil test, it monitors the season-long reserves of available nutrients. It also alerts the grower to potential salt buildup problems in a covered system. Since there is little or no loss of available nitrogen to factors other than plant uptake, ongoing nitrogen management can be adjusted based on residual nitrate levels in the soil.

As the high tunnel industry matured there was an increased incidence of uniformly high or above optimum nutrient levels, when comparing to field soil testing guidelines. With anecdotal evidence of enhanced yields at soil test levels well above established guidelines, it became apparent that the existing testing system was not fully addressing nutrient demands in some highly productive houses. All field soil test interpretations are based on the capacity of the soil to retain and supply nutrients over one or more full seasons. Since many high tunnel soils were exhibiting levels in excess of this inherent capacity, it made sense to start monitoring "free-salt" nutrient levels – those in excess of the soil's retention capacity. This is done using the Saturated Media Extraction (SME) method.

For decades the SME has been the routine method used for greenhouse bench crops grown in soil-less mixes (Warnke, 1998) and also in irrigated soils in arid production systems in the west and southwest (Western States Program, 1998). This became our second testing system for high tunnels, called the Long-Term High Tunnel package. It was developed in collaboration with Vern Grubinger at the University of Vermont, who has been a strong advocate of the SME test for Vermont high tunnel systems.

The Long-Term package is most appropriate for those houses that have been continuously covered and/or aggressively amended, have a relatively high EC level, and very high reserve nutrient levels. Nutrients are monitored and managed at the water-soluble level using the SME system. The SME monitors the pool of immediately available nutrients (nutrient intensity), rather than available nutrients held in reserve (nutrient quantity) measured in a typical field soil test. Organic matter level is also monitored to address soil moisture retention capacity. Interpretation and recommendation guidelines are based on the work of Wittwer and Honma (1979) (fig. 1 & 2). Recommendation guidelines were modified from the original chemical sources to non-chemical sources required by organic production standards (Grubinger, 2012).

Figure 1.

Optimum SME Ranges

GH Tomato/Cuke (Wittwer & Honma)		Current High Tunnel (ME & VT)	
pH	5.8 – 6.8	pH	6.0 – 7.0
NO_3-N	125 – 200 ppm	NO_3-N	100 – 200 ppm
P	8 – 13 ppm	P	1 – 5 ppm
K	175 – 275 ppm	K	150 – 275 ppm
Ca	> 250 ppm	Ca	> 250 ppm
Mg	> 60 ppm	Mg	> 60 ppm
EC	1.5 – 3.0 mmhos	EC	2.0 – 4.0 mmhos

Figure 2.

Estimated fertilizer rates to increase SME nutrient levels

Pounds/1,000 sq. ft needed to raise N approximately 10 ppm	
Blood meal 12-0-0	4.2
Soybean meal 7-1-2	7.2
Alfalfa meal 2.5-2-2	20.2

Pounds/1,000 sq. ft needed to raise P approximately 2 ppm	
Bone char 0-16-0	25
Rock phosphate 0-3-0	133

Pounds/1,000 sq. ft needed to raise K approximately 20 ppm	
Sul-Po-Mag 0-0-22-11Mg	2.6
Potassium sulfate 0-0-52	1.1
Alfalfa meal 2.5-2-2	28.6

Pounds/1,000 sq. ft needed to raise Ca approximately 25 ppm	
Calcium sulfate (gypsum)	7.5
Calcitic lime (low Mag)	7.5
Dolomitic lime (hi Mag)	5.3

Adapted from Wittwer & Honma

The SME test package has worked well for highly-amended systems with high demand crops, such as tomato. In either testing system, very high soluble salt levels (> 4 dS/m) must still be addressed to avoid desiccation damage to crop plants. Salt levels can be reduced, either by uncovering to natural rainfall, flushing with several inches of water, or by physical dilution with peat moss or additional field soil.

Method Comparison and Calibration

The two high tunnel test methods differ fundamentally in at least two ways. Each accesses different pools of available nutrients (quantity vs intensity). There is also a difference in the reporting basis. A conventional field soil test reports available quantity in the dry soil as either parts per million (ppm) or pounds per acre. The SME is reported on an extract basis as mg/liter (ppm in the extract). Because of these differences, there is not a consistent relationship between numerical results for most nutrients. There may also be significant differences between the "Low-Medium-Optimum" interpretation levels. The only consistent relationship is that a Low quantity test will invariably cause a Low intensity reading. However, depending on the frequency of flushing salts, an Optimum or Above Optimum quantity test level will not necessarily correspond to an Optimum or High intensity reading. Therefore, each testing package requires its own interpretation and recommendation system and should be considered separately.

A calibration project was undertaken in 2010 in VT using both soil testing systems run at the University of Maine. Both soil testing systems identified potassium as potentially limiting. Three rates of N and K were applied in a factorial RCB design in an existing tomato house. There was a definite trend in yield response to potassium, but due to a disease-shortened season and high background variability, it was not statistically significant.

Even with a shortened season, fruit yields alone resulted in equivalent nutrient removal on a per acre basis of 200 lb N, 80 lb P and 500 lb K – demonstrating the very high nutrient demand on high tunnel soils. Efforts are ongoing to verify and modify existing guidelines for both Quantity and Intensity testing systems for these very high nutrient demand high tunnel systems.

References:

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