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Soil Salinity in High Tunnel Production

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Understanding soil salinity in high tunnels

There is growing concern about increasing salinity in high tunnel soils, which is measured as soluble salt content. Soluble salts refer not only to sodium (Na^+), but also to other cations in the soil including potassium (K^+), calcium (Ca^+), and magnesium (Mg^+). Anions such as chloride (Cl^-) and nitrate (NO_3^-) are considered salts as well and are often applied in conjunction with K, Ca, or Na by way of fertilizers such as potassium nitrate (KNO_3), calcium nitrate ($CaNO_3$), or sodium nitrate ($NaNO_3$), among others. Soluble salts may also be introduced in soil amendments such as composts and manures, which may carry high levels of salts as well as phosphorus (P). When fertilizers and amendments are added to the soil in excess of the nutrients needed for crop production, they are not properly taken up by plants. This may lead to nutrients being leached through the soil profile or building up near the soil surface or in the crop root zone.

Because high tunnels are typically covered with plastic throughout the year, rain water is not able to affect the soil as it does in an open field environment. This lack of rain means there is far less water flow pushing nutrients deeper through the soil profile. Although this may limit nutrient leaching compared with the open field, this same process also means that salts are not being moved below the rooting zone to the extent they are in the field and may build up to levels that create nutrient imbalances and may even harm the crop (Figure 1).

Photo by Maya Horvath

Figure 1. Tomato plants were grown from March to August in a high tunnel with potassium nitrate applied weekly via fertigation. After removal of the plants and the woven weed mat barrier, salt on the soil surface can be observed (arrows).

Testing for soil salinity in high tunnels

There are several soil analyses available through various soil testing facilities (including the University of Kentucky's Regulatory Services Soil Testing Laboratory) that can help aid in understanding your high tunnel soil's salinity level. Although the tests described below are not part of a "routine soil test" package, they are recommended for high tunnel soils in order to know the content and concentration of the different salts in one's high tunnel soil, even before you suspect you may have a salinity issue. Requesting a soluble salts test on the soil test form is recommended. Many testing laboratories, including the University of Kentucky (UK) Regulatory Services Soil Testing Laboratory, measure soluble salts by measuring the electrical conductivity (EC) of a water extract from a mixture of 1 part soil and 2 parts water. This is referred to as $EC_{1:2}$. Since water is a poor conductor of electricity and dissolved salt ions are a good conductor of electricity, the EC of a soil is a representation of the amount of dissolved salts from the soil. It is important

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Table 1. General electrical conductivity ($EC_{1:2}$) readings and interpretation for vegetable production systems

$EC_{1:2}$ reading (mmhos/cm or dS/m)	Evaluation	Interpretation
0-0.40	Very low	Nutrient levels too low for normal growth
0.41-0.80	Low	Suitable for seedlings and salt sensitive plants
0.81-1.20	Normal	Standard range for most established vegetable crops; upper range for salt-sensitive crops
1.21-1.60	High	Possible reduced vigor and growth, particularly during high temperatures
1.61-3.20	Very high	Possible visible salt injury and reduced growth, including marginal leaf burn and wilting
>3.20	Extreme	Visible salt injury on most vegetable crops

to note that extraction methods for EC may vary, based on soil type and testing laboratory. Other methods of measuring soil EC involve different amounts of water added to soil which will affect the measurement and interpretation of results. Although EC is the standard method for measuring soil salinity for most testing labs in our region, other analyses are sometimes used, such as total soluble salts (TSS) which measures the total mass of dissolved ions in water and is in units of ppm. Total soluble salts is often used in conjunction with the concentration of sodium to evaluate sodium-related salinity (sodicity). Your soil test results should be accompanied by interpretations and recommendations from specialists. A general guide for interpreting $EC_{1:2}$ readings for vegetable production systems is listed in Table 1.

Cation exchange capacity (CEC) is also offered as part of the UK Regulatory Services Soil Testing. CEC is a representation of the cations held in the soil and the availability of nutrients. Clay soils have a higher CEC compared to sandy soils because of the naturally occurring negative charge of clay particles. A soil with a high CEC is generally considered beneficial because of the increased water and nutrient holding capacity of the soil. However, because a high CEC also means that the soil is less likely to leach cations, this may also contribute to increased soil salinity. Typical CEC values for soils of various textures are shown in Table 2. Common CEC values for Kentucky soils are 5 to 15 meq/100 g.

Percent base saturation (BS) is the portion of CEC occupied by the basic cations Ca^{2+}, Mg^{2+}, and K^{+}, as opposed to acidic cations, such as H^{+} and Al^{3+} (Sonon et al., 2017). This value is important in understanding soil fertility. Soils with a high percentage indicate a higher pH (more basic) and therefore have more of a buffer against acidic cations, which can be toxic to plant growth. Depending on the soil, percent BS can be a fraction of or almost equal to CEC.

Not all soil testing laboratories use the same method to determine CEC and base saturation. The UK Regulatory Services Lab provides a value for CEC and base saturation on all soil test reports estimated from routine test results of nutrients and pH. A direct analysis of soil CEC can be requested at an extra cost. For more information on the soil tests conducted and the methods used by UK Regulatory Services, visit https://www.rs.uky.edu/soil/.

Irrigation water may also naturally contain salts, such as Ca, Mg, and Na that may also contribute to increased soil salinity. It is important for growers to be aware of what elements are in the water used to irrigate their crops and how that water may affect the soil (and crops). Growers can submit a water sample for analysis at the University of Kentucky Regulatory Services Soil Testing Laboratory through the Kentucky Coop-

Table 2. Common CEC values for various soil textures.

Soil texture	CEC reading (meq/100g or cmol/kg)	Evaluation
Sand	1-5	Low CEC
Fine Sandy Loam	5-10	Medium CEC
Loam and Silt Loam	5-15	Medium-High CEC
Clay Loam	15-30	High CEC
Clay	>30	High CEC

Adapted from Cation Exchange Capacity and Base Saturation, University of Georgia Extension Circular 1040.

erative Extension Service or through private laboratories. For more information regarding water sample submission and interpretation of the analysis, please refer to UK-Ag Extension publication HO-111.

The effects of soil salinity on plants

Certain plants are more sensitive to soil salinity than others (Table 3). Sensitive plants will exhibit leaf tip burning and yellowing. The leaf margins may also look scorched. However, these symptoms may also be due to other nutrient imbalances or fertilizer burn. A leaf tissue analysis is recommended to confirm the problem. Crops that are sensitive to salts can suffer serious yield reductions. Plants may also display reduced growth that may result in shorter plants and smaller or fewer leaves (Figure 2).

Preventing and remediating salinity in high tunnels

Prevention of the buildup of soluble salts is important to avoid crop yield losses and soil quality issues. Strong preventative measures may also greatly decrease the need to mitigate for high salt levels in the future. Growers can minimize the soluble salt inputs on the soil by limiting the amount of compost, manure, and nitrogen-based fertilizers applied to the soil. Growers should only apply what is needed for the crop and when the nutrients are in demand. This may mean reducing fertilizer inputs and splitting applications throughout the growing season. Consistent soil testing will be helpful in knowing how much, if any,

Photo by Timothy Coolong

Figure 2. Tomato plants in the foreground were grown in soil with approximately 700 lb of Na per acre. Tomato plants in the background were growing in soil with 50-80 lb of Na per acre.

Table 3. Salt sensitivity of select vegetable crops

Vegetable crop	Soil salinity (EC_e) threshold without yield loss (mmhos/cm)	Salinity sensitivity rating
Bean	1	Sensitive
Beet	4	Moderately tolerant
Broccoli	2.8	Moderately tolerant
Cabbage	1.8	Moderately sensitive
Carrot	1	Sensitive
Cucumber	2.5	Moderately sensitive
Lettuce	1.3	Moderately sensitive
Onion	1.2	Sensitive
Pepper	1.5	Moderately sensitive
Sweet potato	1.5	Moderately sensitive
Potato	1.7	Moderately sensitive
Radish	1.2	Sensitive
Spinach	2	Moderately sensitive
Squash	3.2	Moderately tolerant
Strawberry	1	Sensitive
Tomato	2.5	Moderately sensitive
Zucchini	4.7	Moderately tolerant

Adapted from Soil Fertility and Fertilizers: An Introduction to Nutrient Management, 7th edition and Knott's Handbook for Vegetable Growers, 5th edition.

additional nutrients to amend to the soil. For recommendations on the amount of fertilizer to apply and when to apply split applications, please refer to UK ID-36 Vegetable Guide for Commercial Growers.

Cover cropping inside high tunnels is also a strategy that may prevent a buildup of soluble salts. Grass cover crops will help scavenge available nutrients in the soil, can help maintain or build soil organic matter levels, and may help growers reduce composts or other soil organic matter additions. Legume cover crops "fix" atmospheric nitrogen (N_2) via a symbiotic association with microbes in their roots and may provide a significant portion of the following crop's N demand. However, it should be noted that N fixation is significantly reduced if the soil nitrogen levels are already high, as in many high tunnels. In this case, a grass cover crop, such as cereal rye or millet, may be a better fit for the rotation. General recommended seeding rates and planting dates for many cover crops can be found in the Midwest Cover Crops Field Guide. For a copy of this field guide and for more regionally specific guidelines, contact your county extension agent.

Water management is the primary way to reduce soil salinity. Overhead irrigation of bare soil (when crops are not growing) may help leach salts far enough through the soil profile that they will not affect the future crop and can potentially be effective on soils with good structure and drainage. However, a considerable amount of water is required to leach any salts. Prior research indicated that approximately 6 inches of water is needed to leach salts through the soil profile (Table 4). However, a pilot study conducted at the University of Kentucky revealed that this may not be as effective as previously thought (Lark and Jacobsen, 2021). The pilot study was conducted on a Maury silt loam soil in Lexington, KY and evaluated high tunnel leaching using different water volumes applied by micro-jet sprinklers (Figure 3). The conclusion of the study was that 6 in of water did not leach a statistically significant amount of potassium or magnesium from the soil. However, applying 12 in of water leached approximately 60 lb of K/acre and 95 lb of Mg/acre, though this was much less than the formerly estimated 80%.

Table 4. Water volume required for leaching salts through soil profile

Water volume	Percent of salts leached below 12"
6"	50%
12"	80%
24"	90%

Courtesy of the California Fertilizer Association, Western Fertilizer Handbook, 8th Ed.

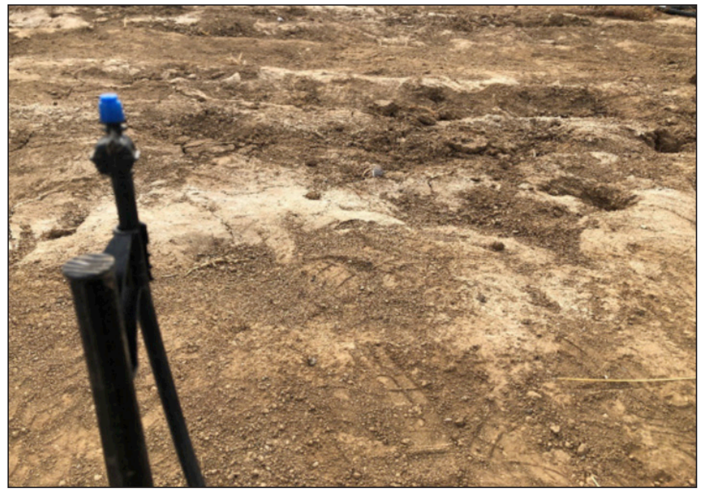

Photo by Ryan Lark

Figure 3. High tunnel soil prior to applying 6 and 12 inches of water using a 180° micro-jet sprayer. Photo was taken prior to applying any irrigation.

Another option for leaching salts may be to take advantage of the rainy season. When it is time to replace the plastic layers on a high tunnel (typically every four or five years), it may be useful to leave the high tunnel uncovered for several months (usually during the winter) to allow precipitation to naturally leach the salts through the soil and out of the root zone. Between the months of November and February, most regions in Kentucky have historically received approximately 15 inches of rain, which would be enough water volume to leach the majority of the salts past the root zone of vegetable crops.

Summary

Prevention of soil salinity through regular soil testing and well-informed applications of fertilizer to your soil will help set you up for future successful production in your high tunnel. The use of cover crops in the place of manure or compost will also help prevent soil salinity. However, buildup of salts in the soil is possible even with careful monitoring of the soil. That is why regularly allowing rain or heavy irrigation to push any salts past the root zone will also be an important aspect of soil salinity prevention.

If salt has already built up in the soil and prevention is not possible, there are strategies for remediation. Leaving the high tunnel uncovered through the winter months to allow any salts to be leached past the root zone is an affordable and relatively easy method of remediation. Because it will take the high tunnel out of production, it may not be possible for all growers. Physically moving the high tunnel to another location on your farm may also be an option.

References

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Photos courtesy of Maya Horvath, UK Horticulture student (Pg. 1), Timothy Coolong, University of Georgia Horticulture Professor (Pg. 3), and Ryan Lark, UK Horticulture Research Analyst (Pg. 4) **March 2022**