Soil Management and Soil Quality in High Tunnel Production Systems

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Growers have indicated that changes in soil quality under production in high tunnels is an important problem, but these have not yet been quantified or critically assessed in the central Great Plains of the U.S.A. We conducted surveys of grower perceptions of soil quality in their tunnels (n=81) and compared selected soil quality indicators (salinity and particulate organic matter carbon) under high tunnels of varying ages with those of adjacent fields at sites in Kansas, Missouri, Nebraska and Iowa in the U.S.A.

Soil was collected from high tunnels and adjacent fields on farms in Kansas, Missouri, Nebraska, and Iowa in the autumn of 2006. Soil collection was focused on high tunnels that had been in place at least three years. Soil was collected adjacent to the high tunnel for quality comparison. Management of the adjacent fields varied. Locations where soil under the high tunnel was not that of the adjacent field (e.g., creek bottom soil had been brought into the high tunnel) were not included in the data set. Soil samples representing a high tunnel or field were a combination of at least five random collections within crop rows. Soil was collected from the surface 5-cm for salinity analysis. Soil particulate organic matter carbon, total carbon, and salinity were determined in soil collected to the 15-cm depth with a soil probe.

Fourteen percent of growers surveyed considered soil quality to be a problem in their high tunnels, and there were significant correlations between grower perceptions of soil quality problems and reported observations of clod formation and surface crusting, and to a lesser extent surface mineral deposition. Grower perception of soil quality and grower observation of soil characteristics were not related to high tunnel age.

Soil surface salinity was elevated in some high tunnels compared to adjacent fields, but was not related to time under the high tunnel (Figure 1.). In the soil upper 5-cm, salinity in fields did not exceed 2 $dS \cdot m^{-1}$, and was less than 2 $dS \cdot m^{-1}$ under 74% of high tunnels, and less than 4 $dS \cdot m^{-1}$ in 97% of high tunnels.

Soil organic matter (SOM) is a commonly used biological indicator of soil quality. Organic matter influences soil structure, nutrient storage, water holding capacity, biological activity, tilth, water and air infiltration. Particulate organic matter (POM) is labile organic matter of size fraction 53 micrometers to 2 mm, and it has the advantage as an indicator of soil quality of faster response to environmental change than SOM. Changes in POM can be used to predict trends in SOM. Particulate organic matter has been correlated to microbial biomass, C and N mineralization, and soil aggregate formation and stability, demonstrating that increased POM indicates improved soil quality. Evaluation of the portion of the soil carbon in the particulate organic matter size fraction can be used for comparison of locations or for comparison of changes over time.

Many growers give high tunnels priority when applying organic soil amendments, so that much of the organic matter in high tunnels may be fresher or less decomposed. In the survey 85% of growers reported the use of organic amendments in their high tunnels. This was also evidenced in analysis of total soil carbon in that 70% of high tunnels were found to have higher total C than their adjacent field, with 16% having double the amount of C. Total carbon under high tunnels ranged from 12 to 125 g $C \cdot kg^{-1}$ soil, and in adjacent fields from 11 to 96 g $C \cdot kg^{-1}$ soil. Soil carbon does not typically exceed 40 g $C \cdot kg^{-1}$ soil (4% of soil mass) in a Mollisol or Alfisol. Total soil carbon was higher than this in 25 % of the high tunnels, but only in 6% of the fields sampled.

Particulate organic matter carbon as a fraction of total carbon ranged from 0.11 to 0.67 g POM $C \cdot g^{-1}$ TC under high tunnels (Figure 2). In the fields, the POM TC^{-1} was 0.10 to 0.89 g POM $C \cdot g^{-1}$ TC. In other studies, POM was observed to make up 10% of total soil C (0.10 g POM $C \cdot g^{-1}$ TC) in long-term arable soil and 0.4 g POM $C \cdot g^{-1}$ TC under grassland. Particulate organic matter carbon exceeded 0.4 g POM $C \cdot g^{-1}$ TC in 26% of high tunnels and 9% of the fields adjacent to high tunnels. It exceeded 0.25 g POM $C \cdot g^{-1}$ TC in 78% of high tunnels compared to 48% of adjacent fields. High tunnel POM TC^{-1} tended to exceed that in adjacent fields, possibly indicating better soil quality under high tunnels. Seventy-three percent of high tunnels had POM TC^{-1} in excess of the adjacent field, indicating that soil organic matter under high tunnels tends to be less decomposed than in open fields.

The effect of high tunnel age on the quality of the soil was one objective of this study. The ages of high tunnels sampled on farms ranged from one to fifteen years. The median high tunnel age was five years. Grower perception of soil quality did not differ with age of high tunnel. Growers with tunnels in situ for two to 15 years reported good soil quality (n=41). Growers who reported soil quality problems had tunnels ranging in age from three to eleven years. Observations of negative soil attributes (surface clod, crust formation, and hardpan presence) were not related to time under a high tunnel.

Measured indicators of soil quality were also not correlated to the age of high tunnels. Salinity was not significantly correlated to high tunnel age. The POM TC^{-1} in high tunnels was also poorly correlated to tunnel age. The portion of soil C made up by the POM fraction differed between high tunnel and adjacent field, but this difference was not because of the length of time a high tunnel covered the soil, as indicated by the lack of correlation between POM HT:Field and tunnel age

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Figure 1. Salinity in the surface upper 5-cm at (a) sixty-three field locations adjacent to high tunnels and (b) ninety-three high tunnels in the central Great Plains, arranged from newest to oldest from left to right, and (c) salinity in the soil upper 15-cm in the high tunnels with salinity exceeding 2 dS·m^{-1} in the upper 5-cm.

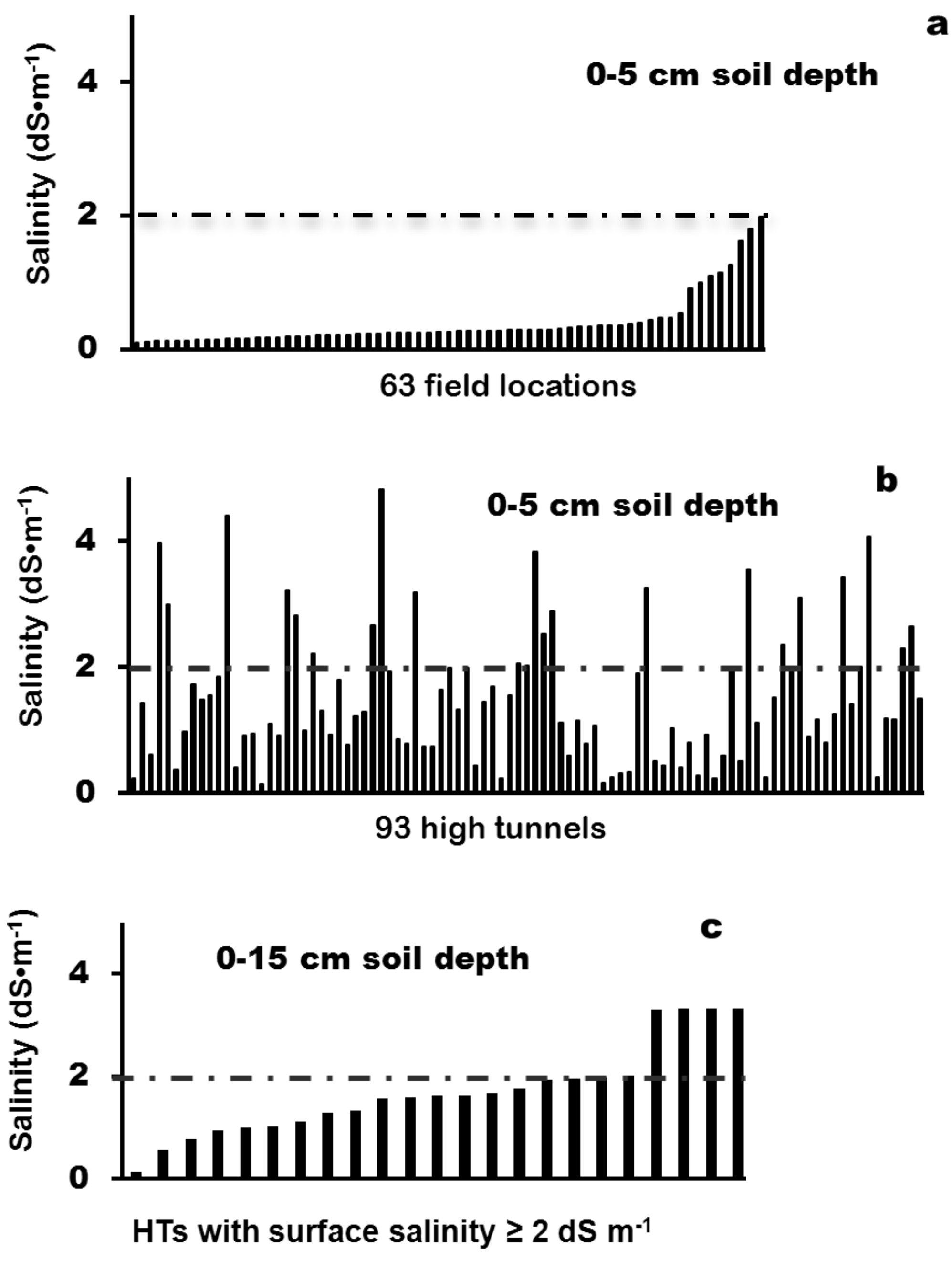

Figure 2. Particulate organic matter carbon as a fraction of total soil carbon in high tunnel and field, and the age of the high tunnel with matching x-axes indicating 93 high tunnels sampled in 2006.