Optimizing Drip Irrigation for Organic Systems

Effect on Soil Function, Root Systems, and Productivity of Corn and Tomato

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Background

Seventy percent of California's total tomato crop is now under drip irrigation[1], with benefits for fruit yield and quality[2]. Less is known about the effects of drip irrigation in organic systems, where nutrient management using fertigation techniques is unavailable, or about how water distribution patterns affect organic nutrient availability, root growth and subsequent crop yield.

We hypothesized that the main limiter of organic crop productivity under drip irrigation is nutrient mobilization, due to the small, discrete wetting pattern around a drip line, and that redistributing water using a double (parallel) line could improve performance.

The Russell Ranch Century Experiment at UC Davis examines the long term effects of crop rotation and management system on yield, profitability, and resource use efficiency. At Russell Ranch, we compared two configurations of sub-surface drip irrigation to furrow irrigation in a corn/tomato/winter leguminous cover crop rotation system for their effect on:

- **Water** and **nutrient** distribution throughout the bed
- **Root growth**/density response relative to location of available water at different depths
- **Weed pressure**
- **Productivity**

Methods

Layout and crop management: 6 plots (3 tomato, 3 corn), partitioned into 6 rows of single-line Drip irrigation, 6 rows double-line drip, and the remainder furrow. 2 T/acre chicken manure trenched (drip) or spread on top of bed (furrow).

Yield: For corn, machine harvest of three ~100 m adjacent strips, grain threshed and dried to stable weight. For tomato, machine harvest of one ~200 m strip, fruit fresh weight.

Weeds: Survey of ten 0.25 m^2 quadrats per treatment/plot, 1-2 days after irrigation.

Water: Gravimetric water content for 25 g soil subsamples taken from a grid of three depths and three distances relative to the water source in the bed (**Fig 1**).

Nitrate: Same sampling grid as above, 5 g field moist soil extracted with 25 mL 2.0M KCl. Colorimetric analysis using a single vanadium(III) chloride reagent for nitrate concentration (ppm).

Roots: Minirhizotrons installed within 1 wk. after planting. Bi-weekly scan with a CI-600 In-Situ Root Imager (CID Bio-Science). Manual mapping followed by root/background differentiation and color analysis using WinRhizo Pro 2013.

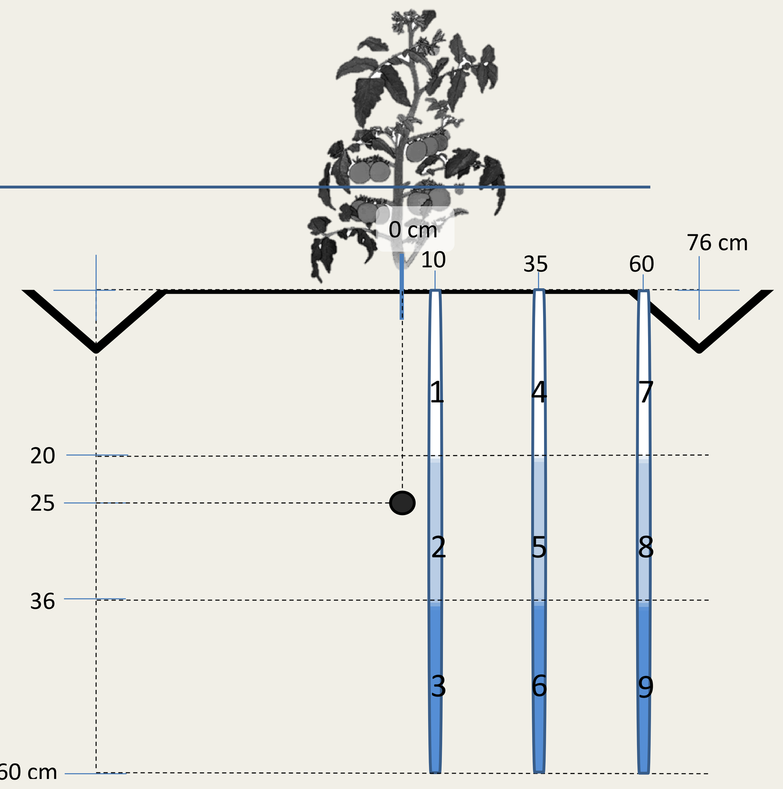


Fig. 1: Schematic of soil sampling grid giving subsample positions in relation to drip line. Three replicate grids were sampled at 1 ft. intervals along the bed to account for emitter position.

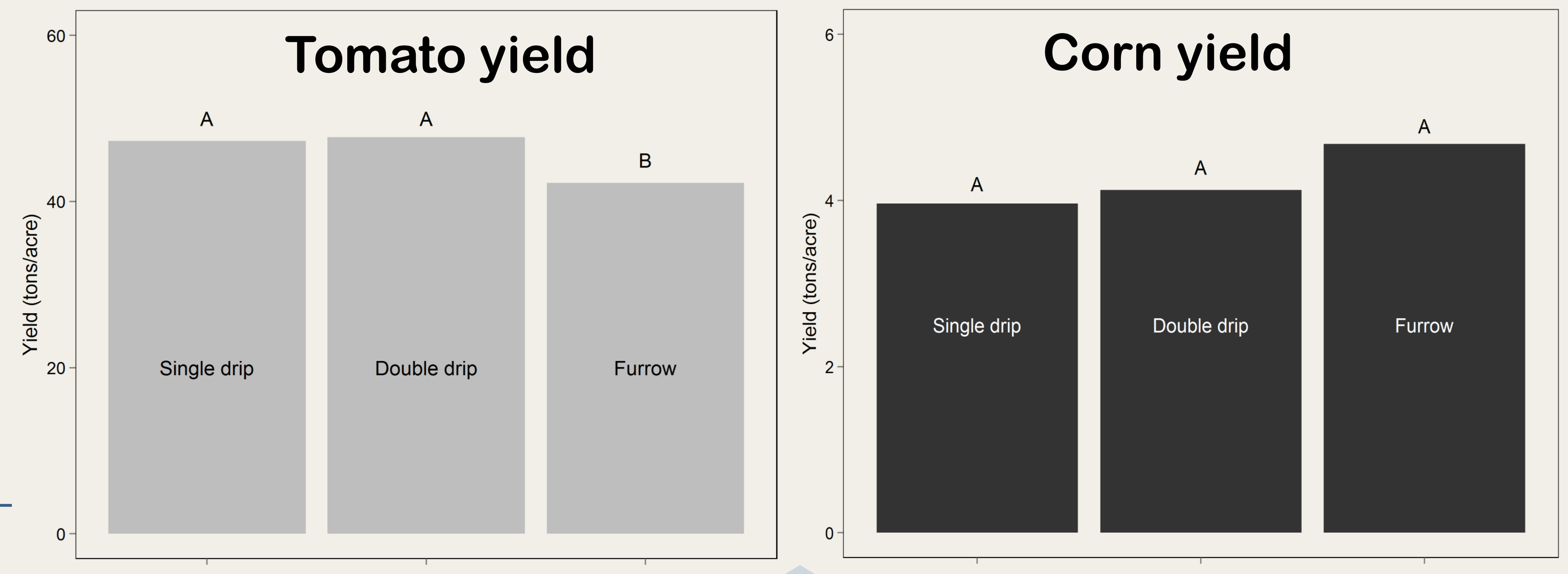


Fig. 2: Tomato yield (fresh weight US tons/acre) derived from machine harvest of ~200 x 5 ft. strip. Corn yield (dry grain weight US tons/acre) from machine harvest of 3 adjacent 125 x 5 ft. strips.

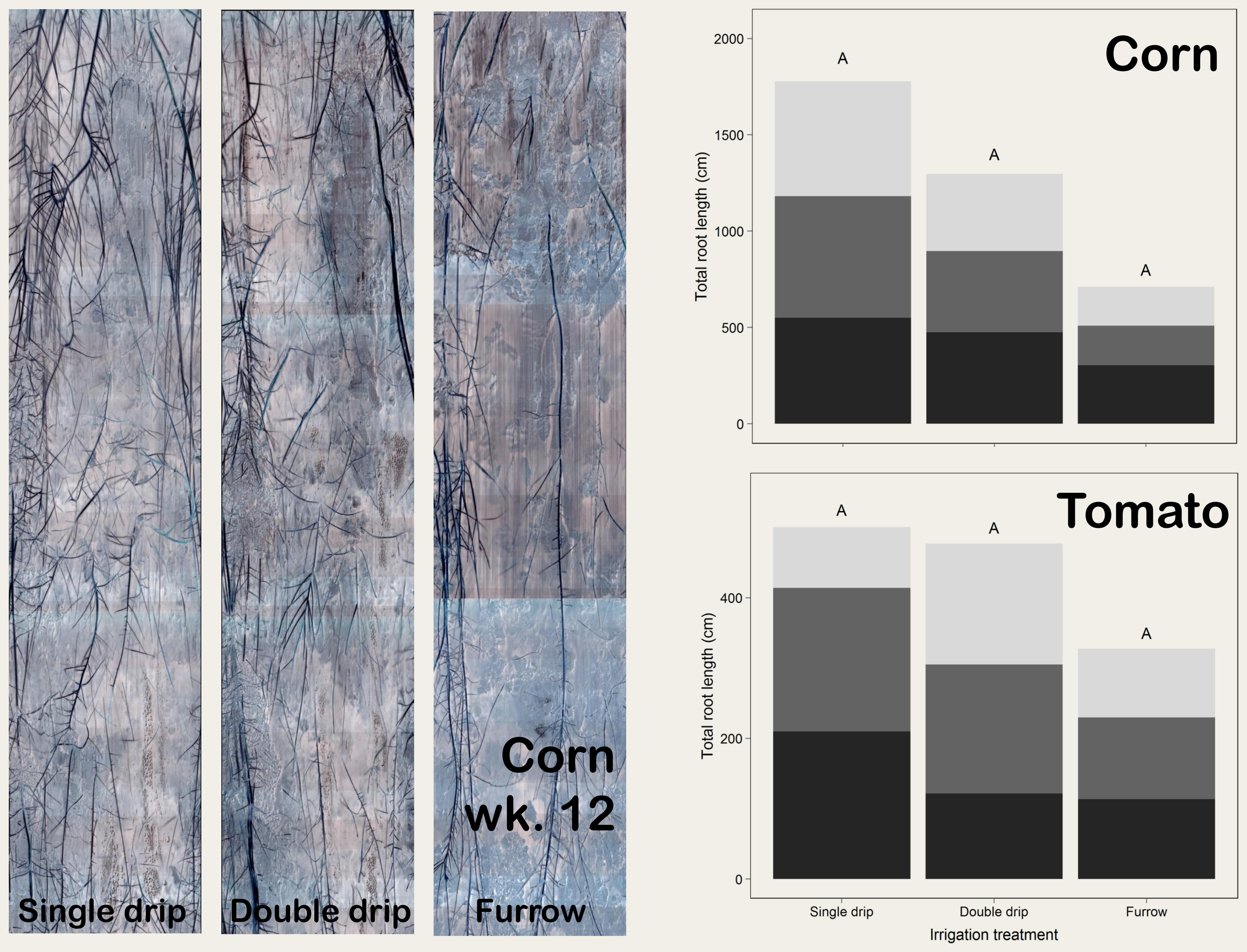
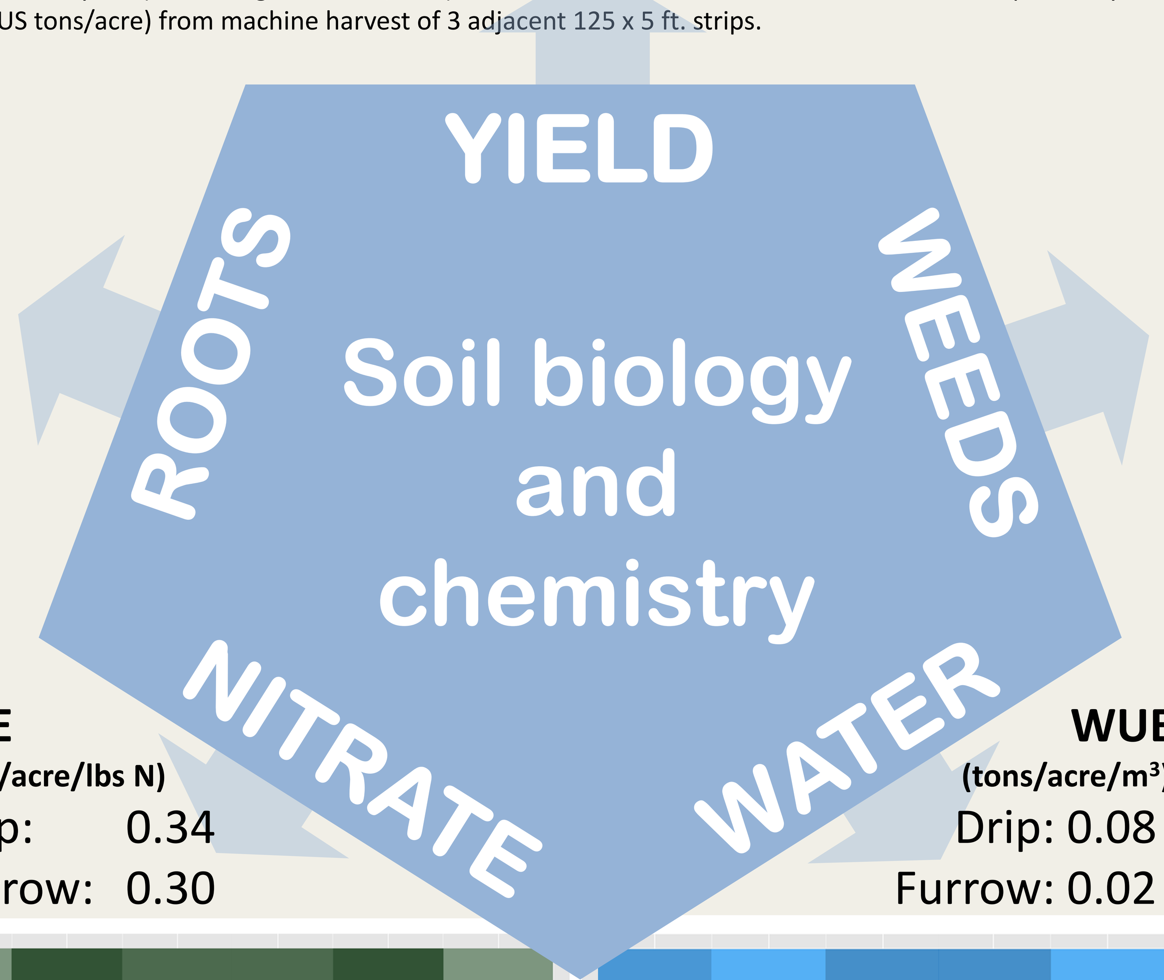


Fig. 5: LEFT False color root scans from in-situ Rhizotron tubes for the three irrigation treatments, and RIGHT average total root length (cm) on the final scanning date for tomato (7/21/2015) and corn (9/7/2015).



NUE (tons/acre/lbs N)
Drip: 0.34
Furrow: 0.30

WUE (tons/acre/m^3)
Drip: 0.08
Furrow: 0.02

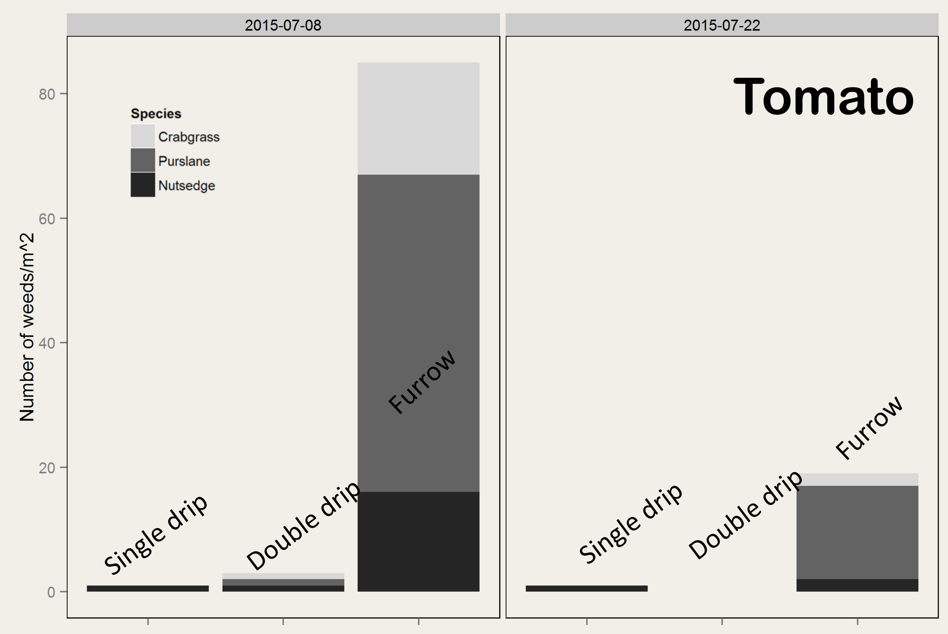


Fig. 3: LEFT Abundance (#/m2) of the three dominant weed species at two sampling dates in tomato plots for drip and furrow irrigation treatments. RIGHT False color composite aerial image of tomato and corn plot showing differentiation between drip and furrow treatments (Source: TerrAvion 2015).

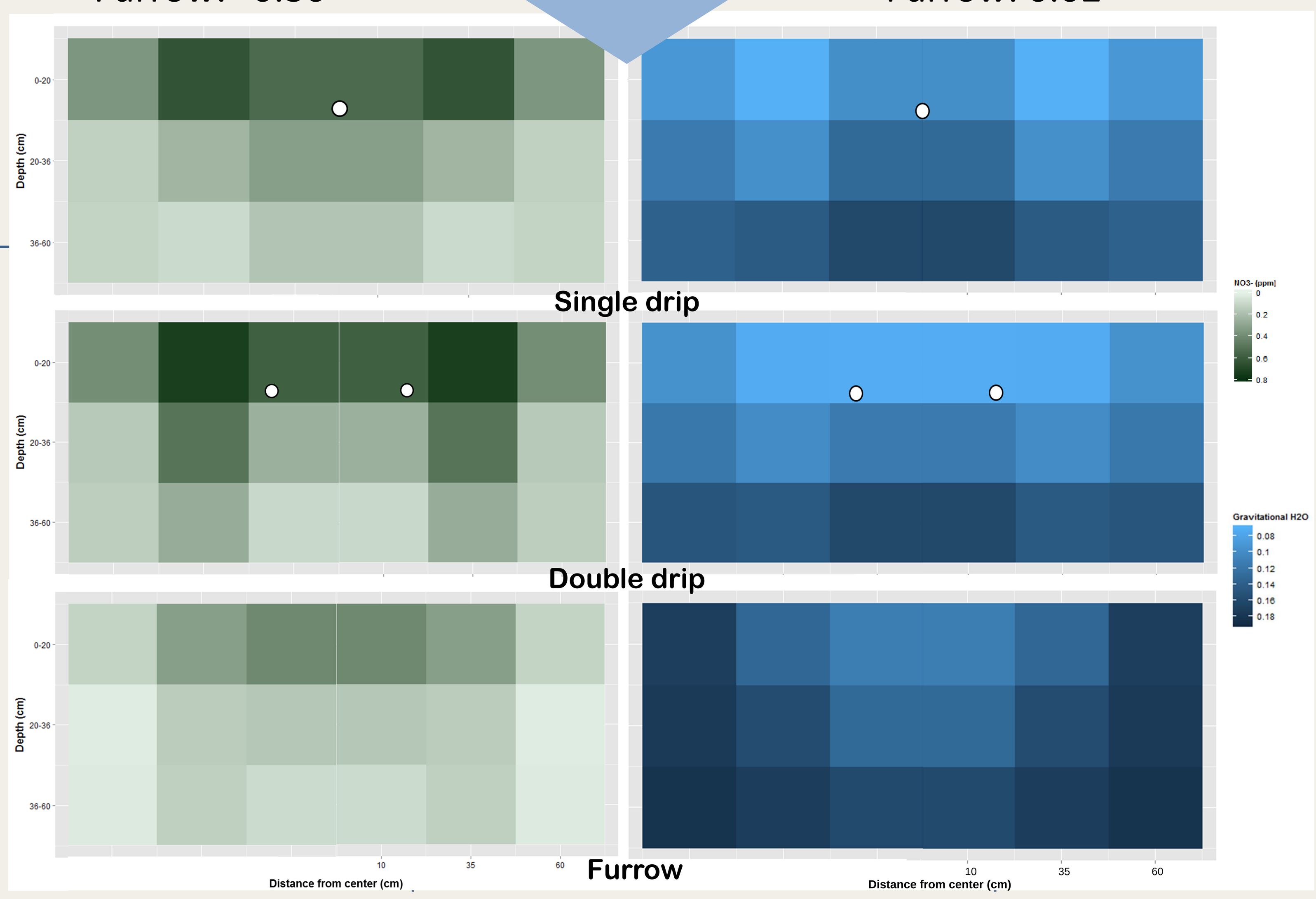


Fig. 4: Cross-section of bed showing heatmap of LEFT NO_3^- concentrations (ppm) and RIGHT gravimetric water content for tomato plots.

Results/Discussion

No great differences were observed between single-line and double-line configurations of sub-surface drip in terms of **water** and available **nitrate distribution** (**Fig. 4**). However, drip differs from furrow in both lateral and vertical distribution of water and nitrate. Nitrate is highly concentrated at the surface near the site of compost trenching in the drip treatment, whereas it is spread more evenly in the furrow treatment.

Both corn and tomato root systems show a trend of **greater root proliferation** in the drip treatments than in the furrow treatment, but indications of plasticity of root growth response to resource availability at different depths are weak (**Fig. 5**). Weed abundance in tomato plots was significantly greater in the furrow compared to the drip treatment (**Fig. 3**).

Design and management of irrigation systems affect the spatial and temporal availability of water for crops. In turn, management can interact with agroecosystem processes, especially as they relate to soil biological, chemical, and physical properties. Tradeoffs and externalities resulting from these interactions have implications for agroecosystem C and N cycling, C sequestration, and N mineralization over the longer term.

These preliminary data suggest that weed pressure is an important limiting factor for tomato production, whereas water stress is a more important limiter for corn. These limitations were reflected in the **improved yield for tomato** as compared to the **depressed yield for corn** under drip irrigation (**Fig. 2**).

Next steps

Characterization of larger-scale parameters of interest, e.g. water-use efficiency, water quality and greenhouse gas mitigation, will require research on the effects of drip irrigation on soil physical parameters in addition to the chemical and biological elements examined here. Interactions among these parameters will have implications for infiltration and soil water release, soil OM accumulation and C sequestration, and consequently for the capacity to build soil natural capital in organic, drip-irrigated systems.

Efforts to improve water- and nutrient-use efficiency in drip systems must consider short- and long-term goals, economic feasibility, and differences in crop physiological requirements.

These are preliminary data from a single field season; they will be expanded to include 1-2 more field seasons by 2017. Several analyses are in progress that will be included in later reports on this research:

- Microbial activity based on colorimetric FDA enzyme analysis
- Total C and N content of corn and tomato biomass samples with Elemental Analyzer
- Decomposition rate for leguminous cover crop using litter bag method

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