N.C. STATE UNIVERSITY
DEPARTMENT of SOIL SCIENCE

Tillage Options in the N.C. Piedmont: Constraints and Potential for Soybean Production

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Soybean and Tillage Field Day ♦ 05 September 2012 ♦ Upper Piedmont Research Station, Reidsville, N.C.

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NORTH CAROLINA SOYBEAN PRODUCERS ASSOCIATION, INC.

Rationale

North Carolina is one of the 18 largest soybean producers in the United States. However, N.C. has the lowest 10- and 20-year yield trends, the 3rd lowest 5-year trend and, the lowest yield trend in all three categories compared to peer producers in other southern states AR, KY, LA, MS, TN (**Figure 1**).

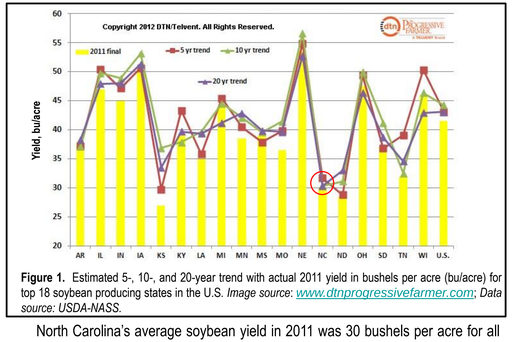


Figure 1. Estimated 5-, 10-, and 20-year trend with actual 2011 yield in bushels per acre (bu/acre) for top 18 soybean producing states in the U.S. *Image source:* www.dtnprogressivefarmer.com; *Data source: USDA-NASS.*

North Carolina's average soybean yield in 2011 was 30 bushels per acre for all production categories (full-season, double crop, irrigated and non-irrigated); yield indicators over the past decade have trended flat to erratic (**Figures 2a** and **2b**).

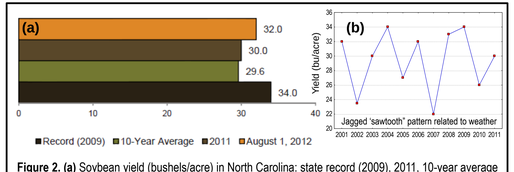


Figure 2. (a) Soybean yield (bushels/acre) in North Carolina: state record (2009), 2011, 10-year average and predicted 2012 yield; and **(b)** North Carolina trend 2001-2011. *Source: USDA-NASS News Release, August 12, 2012 and USDA-NASS.*

Average soybean yield for Rockingham County (site of the Upper Piedmont Research Station) in 2010 was 28 bu/acre and 18 bu/acre in 2011 for all production categories. Top soybean producers in North Carolina regularly crack 80+ bu/acre, indicating that higher yields are attainable. We point up that the top three North Carolina soybean yields in 2011 were from producers in the Piedmont and Mountain regions (Union and Yadkin Counties). Kip Cullers, of Purdy, MO, holds the world record for soybean production, producing a whopping 160.1 bu/acre in contest plots in 2010. The soybean champ said the key to realizing higher yields is keeping soybean plants healthy and stress-free the entire growing season.

Drought stress is a major factor limiting soybeans in N.C. Ideally, all soybean acres would be irrigated. However, due to economic costs or a lack of storage water, many soybean acres are rainfed. Here, we discuss how tillage affects soil water dynamics in soybeans, research findings from our long-term (28-yr) tillage plots, and the potential for boosting soybean productivity in the N.C. Piedmont.

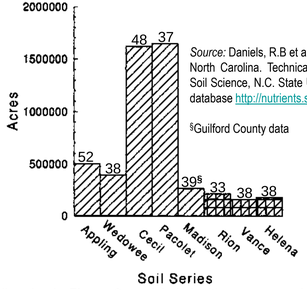
Soil: The Ideal and the Real

What would an 'ideal' soil look like? Here's our profile:

- Deep rooting zone, easily permeable to air, water, and roots
- Good water-holding capacity
- Balanced nutrient supply
- Good aggregate structure resistant to erosion

Most agricultural soils in the Piedmont fall short of this ideal! **Figure 3** shows a breakdown of the dominant soils in the N.C. Piedmont felsic crystalline soil system and their yield potential for soybean in Rockingham County (full-season, non-irrigated, representative slope).

Figure 3.



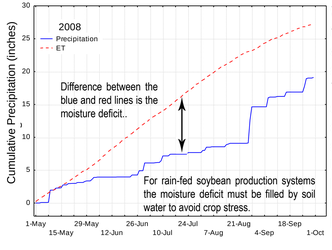
Source: Daniels, R.B et al. (1999) Soil Systems in North Carolina. Technical Bulletin 314. Dept. of Soil Science, N.C. State Univ. and Realistic Yield database http://nutrients.soil.ncsu.edu/yields/

§Guilford County data

The soil series in **Figure 3** are labeled with average soybean yield numbers from 33 to 52 bu/acre. The largest acreages are occupied by the Cecil and Pacolet series, many which are under row crop production. All the soils in **Figure 3** have one thing in common: a sandy loam to sandy clay loam surface texture (uneroded). *Then why the large spread in average soybean yield??*

The answer lies in the subsoil, specifically differences in physical and chemical properties that influence crop rooting and water holding capacity, two key properties of our 'ideal' soil.

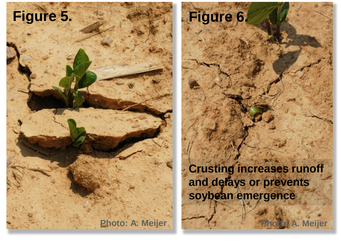
Weather: Future Uncertain, but Predictable Events



Weather is a wildcard variable that farmers have no control over. Some weather events are, however, quite predictable. The chart at left shows cumulative reference evapotranspiration (ET) vs. actual precipitation at the UPRS in 2008. Rainfall below ET during the soybean season (May-Oct) is normal in the N.C. Piedmont.

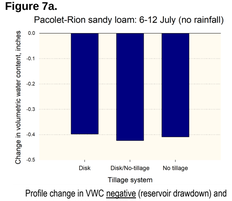
Tillage and Soil Water

Tillage strongly controls the amount of water that enters the soil via infiltration. Infiltration occurs at the soil surface. Inversion tillage often buries all the residue from last season's crop, leaving a clean surface. Heavy rains beating down on the exposed mineral soil causes slaking and collapse of aggregate structure. The result is a hard, thick surface crust (**Figures 5** and **6**).



Our research group has monitored profile soil water in the Reidsville tillage plots beneath two corn crops (2009, 2011) and three soybean crops (2008, 2010, 2012) weekly at 4, 8, 12, 18, 24, and 36" depth with a Dynamax PR2/6 capacitance probe http://dynamax.com/products/soil-moisture. **Figures 7a-d** show profile moisture beneath soybean measured at 06, 12, and 19 July 2012. No rainfall was recorded at the research station between 06-12 July; on 13 July there was 0.06 inches of rain followed by a brief, very intense storm on 14 July that dropped 3.43 inches. See chart annotations for the interpretive summary…

Figure 7a.



Profile change in VWC negative (reservoir drawdown) and about equal across tillage systems

Figure 7c.

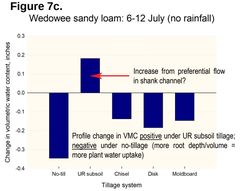
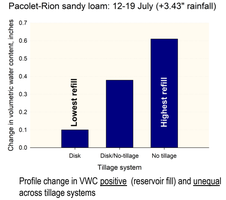
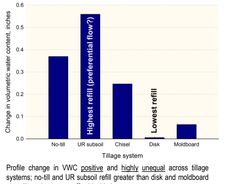


Figure 7b.



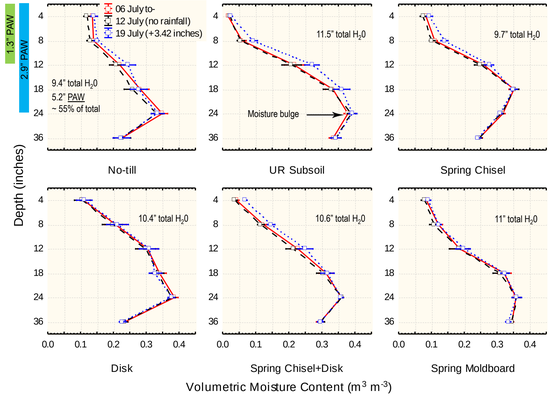
Profile change in VWC positive (reservoir fill) and unequal across tillage systems

Figure 7d.



Profile change in VWC positive and highly unequal across tillage systems; no-till and UR subsoil refill greater than disk and moldboard plow tillage (=more runoff); chisel in-between.

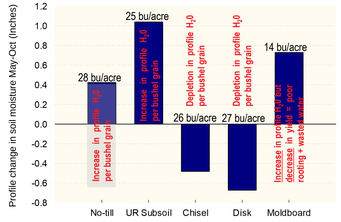
Figure 8.



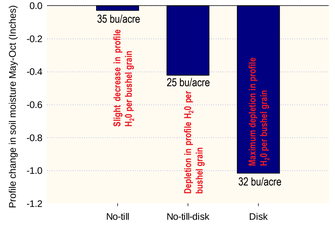
Panels in **Figure 8** (above) show typical profile moisture in a Wedowee sandy loam soil beneath soybean at three measurement dates between growth stages R1 (beginning bloom) to R2 (full bloom). Important findings from these data:

- Total profile volumetric water content (VWC) to 36 inches deep was 9.4 to 11.5 inches across six tillage systems on 19 July.
- Based on measurements of available water capacity, the amount of plant available water (PAW) under no-till was 5.2 inches or ~55% of total profile H_2O.
- In all tillage systems there was a moisture 'bulge' or surplus in the subsoil around 18-24 inches deep; this is potentially available water depending on how deep the soybean roots penetrate.
- Under no-tillage, the upper 12-inch soil profile had 1.3 inches of PAW; at critical soybean growth stages R1 (beginning bloom) through R6 (grain maturity), water use is 0.20-0.30 inches per day; if soybean roots are limited to the upper 12 inches a recharge of 1.3 inches of H_2O is needed every 4 to 7 days to avoid crop stress. This represents a constraint on soybean production.
- Increasing rooting depth to 24 inches would increase PAW by 2.9 inches, enough H_2O to last 10 to 15 days without crop stress. This represents a potential for soybean production.
- Under no-tillage, the profile VWC curve was steeper compared to other tillage systems; our interpretation is that more water is being extracted, and less water is accumulating in the soil profile under no-tillage.
- In all tillage systems, soil water content 24 inches deep was accumulating (=moisture content greater than field capacity=drainage water); soybean rooting through this depth is questionable.

Wedowee sandy loam 2-yr average (2008, 2010) cumulative profile change in soil moisture (May-Oct.) vs. average soybean yield



Pacolet-Rion sandy loam 2-yr average (2008, 2010) cumulative profile change in soil moisture (May-Oct.) vs. average soybean yield.



Interpretive Summary

- Low available soil water content in the soybean root zone is a major factor limiting rainfed production in the N.C. Piedmont.
- Subsoil characteristics strongly influence soybean yield potential.
- We detected a surplus of potentially available water 18 to 24 inches deep beneath soybean in a Pacolet and Wedowee sandy loam soil; other Piedmont soils with loamy, fine-textured B horizons are expected to have similar reserves.
- Tapping available water in the subsoil zone may require modifying the subsoil via innovative non-inversion deep tillage to promote deeper soybean rooting.
- In rainfed cropping, no-tillage and non-inversion tillage have shown better long-term yield resilience and efficiency in terms of seasonal profile water utilization.
- No long-term yield advantage has been demonstrated from annual shallow (9-10") under-row, narrow point subsoiling compared to continuous no-tillage at Reidsville.