DEEP ROOTED COVER CROPS FOR MANAGING SOIL COMPACTION

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Abstract

Soil compaction is a significant problem in the Southeastern USA. This compacted zone or hardpan limits root penetration below the layer and reduces yield, limits productivity and makes plant more susceptible to drought stress. Deep rooted cover crops can penetrate the compacted soil zone and create channels which cash crop roots, such as cotton, would follow to capture needed moisture and nutrients from the subsoil. This reduces and/or eliminates the need for annual deep tillage. Field studies were conducted for two years with three different soil types to determine the effects of cover crops on soil chemical and physical properties, crop responses, and pest pressure. Results showed that cover-crop significantly reduced soil compaction, increased cotton lint yield, increased soil moisture content, reduced nematode population densities, and increased available P, K, Mn, and organic matter content compared to no cover crop.

Introduction

Chronic soil compaction is a significant problem in many soils in the mid-South and Southeastern USA. Although, reasons for compaction are not fully understood, it is assumed that low organic matter content and the nonexpanding clay make these soils susceptible to compaction (Siemens et al., 1993). These soils also have extremely low water holding capacity (less than 0.1 inch/inch) due to predominantly sandy texture with very low organic matter content (less than 1%). Therefore, even relatively short drought periods will have devastating effects on crop yields. Soil horizon in this region is comprised of three distinct layers: A horizon -- sandy to loamy sand, E horizon -- yellowish-brown sandy to sandy clay, and Bt horizon -- sandy clay loam (Figure 1). The E horizon has higher bulk density, lower permeability, and lower water holding capacity. This compacted zone or hardpan usually is about 10 to 16 inches deep and ranges from 2 to 8 inches in thickness. The hardpan layer limits root penetration below the plowing depth and reduces yields, limits productivity, and makes plants more susceptible to drought stress. The E horizon must be broken so that roots can grow into the subsoil or Bt horizon, which contains a majority of moisture and nutrients in the soil profile. Soil compaction management in the Southeastern USA relies heavily on the use of annual deep tillage. For example, the conventional cotton production systems in the coastal plain region require a minimum of three and often five field operations at a cost of approximately $40 per acre.

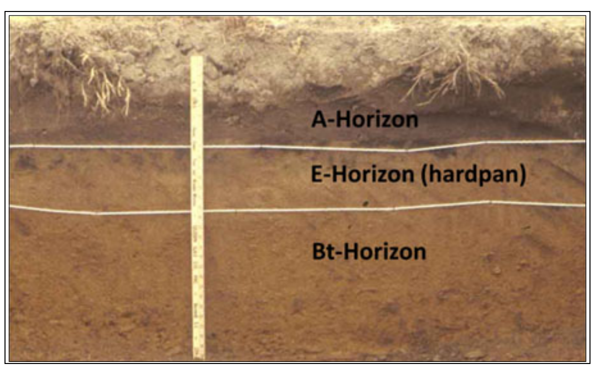

Figure 1. A typical soil profile of the Southeast Coastal Plain soils

There is a great interest in avoiding annual deep tillage to reduce costs, increase residue cover, and buildup soil organic matter. Our research has shown reconsolidation of the hardpan layer from one season to another in some sandy soils of South Carolina. However, the residual effects of deep tillage operations were extended for several years, using controlled traffic scheme and planting directly into the previous year's subsoiler furrow (Khalilian et al., 2004).

The use of cover crops is an increasingly popular sustainable farming practice that provides many benefits to the soil and subsequent cash crops. Cover crops increase soil organic matter (SOM) or soil humus, which provides greater water infiltration and available water holding capacity (AWC). Our results from a previous 4-year study (Khalilian et al., 2002a and b) showed that increasing SOM in Coastal Plains sandy soils would significantly increase crop yields (38%). We attributed the yield increase to improvements in both chemical and physical properties of the soil. Deep-rooted cover crops may penetrate compacted soil better than fibrous-rooted species; therefore, be better adapted for use in "biological tillage" (Chen & Weil, 2010; Williams & Weil, 2004). Deep rooted cover crops, such as rye and “Tillage Radish”, can penetrate the compacted soil zone and create channels for the cash crop roots, such as cotton, to follow and capture moisture and nutrients from below the hardpan layer. This would reduce and/or eliminate the need for annual deep tillage (a requirement in coastal plain soils for optimizing crop yields), reduce fuel consumption, and increase soil organic matter and crop yields. Williams and Weil (2004) reported that soybean yields were significant greater following a cover crop. Cereal rye left thick mulch layer on top of the soil, resulting in conservation of water early in the season. The root channel left by cover-crop, provided soybean roots with low resistance path to subsoil water.

For agriculture to stay viable and profitable, farming practices that conserve soil, reduce crop inputs, and enhance drought resilience must be employed. Residues associated with cover crop have the potential to reduce nitrogen needs in the subsequent cash crop (Sainju et al., 2002). For example, rye cover crop enriched available soil nitrogen and reduced the amount of nitrogen fertilizer required by the subsequent cotton and grain sorghum crop (Sainju et al., 2006). The objective of this study was to determine the effects of rye cover crop on soil chemical and physical properties, crop responses, and pest pressure.

Materials and Methods

Replicated tests were conducted for two years in a production field with three different soil types: Faceville loamy sand, Fuquay sandy loam, and Lakeland sand. Table 1 shows soil characteristics of the test areas. The 6-acre field was located near Blackville, South Carolina (Latitude 33˚ 20″N, Longitude 81˚ 19″W). Table 1 shows soil characteristics of the test areas. At the initiation of the project, intensive soil samples were collected from these different soil types to measure depth to the Bt horizon and to determine soil texture. Also, the field was mapped for variation in soil texture, using a soil electrical conductivity (EC) measurement system (Veris-3100; Veris Technologies Inc., Salina, KS). Soil texture, organic matter, and moisture contents are main factors affecting the EC values. The test field was divided into three management zones based on soil type and soil EC values and 48 rectangular plots (4-row by 60 ft.) were established in each zone, for a total of 144 plots in the test field (Figure 2).

Table 1: Soil classification and texture of the test areas.

Soil type	Family	Sand (%)	Clay (%)
Faceville	*Clayey-kaolinitic - thermic, Typic Paleudults*	78.3	12.5
Fuquay	*Loamy-siliceous-thermic, Arenic Plinthic Paleudults*	85.5	8.9
Lakeland	*Siliceous-thermic-coated, Typic Quartzipsamments*	89.5	6.3

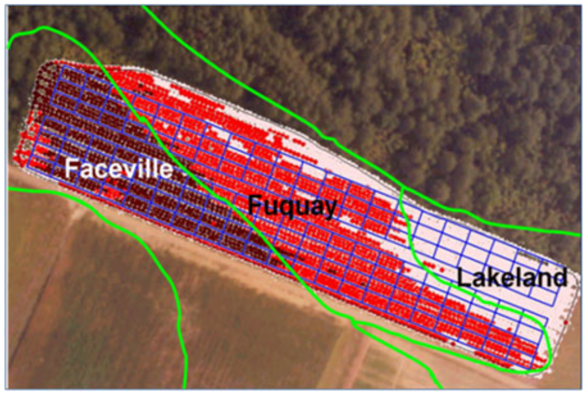

Figure 2: Soil type, EC zones and plot arrangements of the experimental field.

The following treatments were replicated 8 times in each soil type using a randomized complete block experimental design (2x3 factorial arrangements):

Tillage: Deep tillage, no-till
Cover Crop: Rye, Tillage Radish, None

Cover crops were planted around mid-November each year, with either deep tillage using a Worksaver Terra-Max or without a tillage operation. Biomass samples were taken from each plot and the cover crops were terminated each spring using appropriate herbicides. The cotton variety Phythogen 495W3RF was planted in all experimental plots without surface or deep tillage operations using a JD vacuum planter equipped with row cleaners. To eliminate some problems associated with planting cotton into killed cover crop, due to interfere of planters/row cleaners with crop residue, the grain drill for planting cover crop was modified by blocking seed tubes every 38 inches to create skip rows for planting cotton.

To determine the effects of different treatments on soil compaction, a microcomputer-based, tractor-mounted recording penetrometer was used to quantify geo-referenced soil penetration resistance during the growing season. Soil compaction values were calculated from the measured force required pushing a 0.5-in^2 base area, 30-degree cone into the soil. Compaction data were collected 6-weeks after planting cotton and at the end of the growing season.

Twelve sets of EC-5 capacitance moisture sensors (Decagon Devices, Inc.) were installed at three depths (6”, 12”, and 18”) to determine the effects of cover crop on soil moisture contents. In each soil type, four sets were installed in no-till and deep tilled cotton plots with and without cover crop. Em50R wireless radio data loggers were used to automatically read the sensors and store soil moisture data every hour. Also, an automatic and a manual rain gauge were installed in this field to quantify daily rainfall. Cotton was harvested around Mid-October, using a spindle picker equipped with an AgLeader yield monitor and a GPS unit to map changes in lint yield within and among treatments to determine the effects of cover crop and tillage treatments on cotton yields in coastal plain soils.

<u>Results and Discussion</u>

We had an excellent rye cover crop in all plots except on Lakeland sand soil type. This soil had a very high sand contents and low water and nutrient holding capacities. The soil type had a significant effect on the amount of cover crop biomass. The rye biomass in test plots averaged at 490, 2250, and 5136 lbs./acre in Lakeland, Fuquay, and Faceville soil types, respectively (Figure. 3). In both years, we established a good tillage radish cover crop; however, due to cold winter (below 10^o F), most of the tillage radishplots died. Therefore, measurements from plots with tillage radish cover crop were not included in the analysis of yield or soil health data.

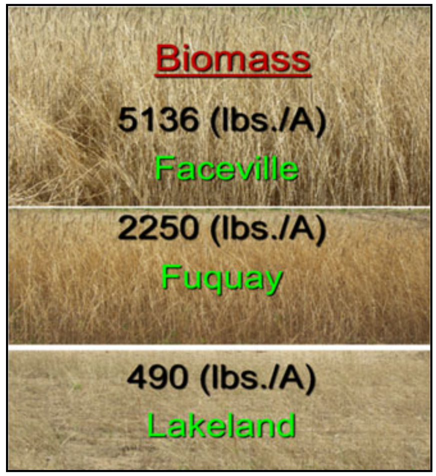

Figure 3. Cover crop biomass for 3 soil types.

The effects of cover crop and tillage on soil compaction were measured using a soil penetrometer. Cone index values exceeding 300 psi, limits root penetration below the compaction layer, reducing yields, and making plants more vulnerable to drought stress. In no-till plots, cover-crop significantly reduced soil compaction (Figure 4) in the E-horizon (10-15 in depth). This could be due to deep-rooted cover crop (rye) penetrating compacted soil layers during the fall when the soil was wet and soft. Averaged over the entire field, cone index values in cover crop plots were below the 300 psi level measured at the end of the production season in a cotton field. In Coastal Plain soils with chronic soil compaction, this could help create and maintain open channels in the subsoil furrow for subsequent years. There were no significant differences in soil compaction between plots with and without cover crop when a deep tillage operation was performed at planting of the cover crop. Tillage significantly reduced soil compaction compared to no-till.

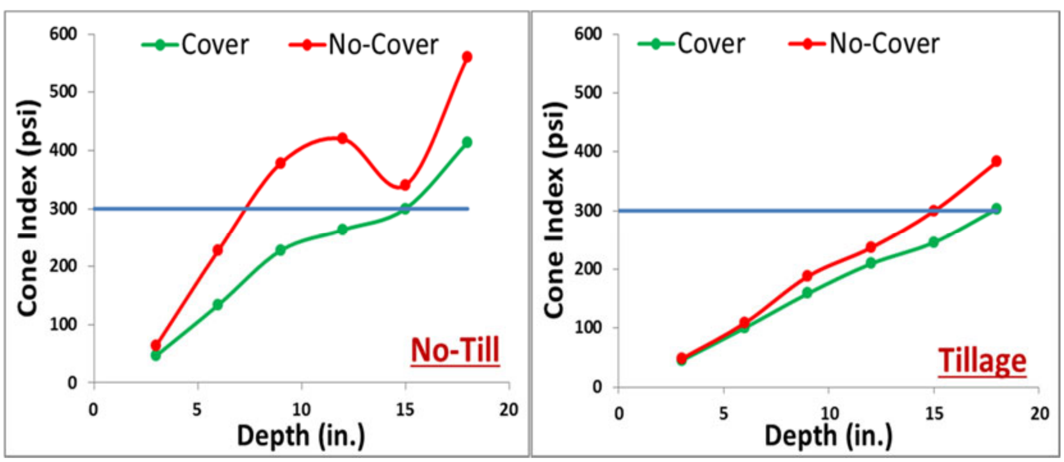

Figure 4. Effects of cover crop and tillage on soil compaction.

Reductions in soil compaction in the E-horizon, due to cover crop, significantly increased cotton lint in the no-till plots (Figure 5). Averaged over three soil types, the yield increase was 38%. In addition, since cover crop eliminated the hardpan layer for the subsequent cash crop, saved growers additional money for not performing deep tillage operations. Soil type had a major effect on the yield increases due to cover crop. Yield increase on Faceville loamy sand was 49% followed by Fuquay sandy loam 32% and Lakeland sand 22%. These results were opposite to what we were expecting since the Lakeland soil had 90% sand content followed by Fuquay 85%, and Faceville 78%. We were expecting that yield increase due to cover crop should be higher in lighter soil texture, since organic matter would increase soil water holding capacity and subsequently increase yield. However, biomass from cover crop rye in

Lakeland soil was almost 10 fold lower than Faceville loamy sand soil. Therefore, there was insufficient biomass in Lakeland soil to affect crop yield. There was a strong linear correlation between cover crop biomass and cotton yield increase (R2= 0.999).

Figure 6 shows an example of higher soil moisture content due to cover crop in Faceville soil type in 2014. Cover crop increased soil moisture contents in this soil by about 4 percentage point. In sandy soil (Lakeland) the difference in soil moisture for the same period was not significant.

Cover crop reduced weed biomass in cotton plots and required less herbicide inputs compared with the conventional system (no-cover). Cover crop positively impacted soil properties by significantly increasing available P, K, Mn, and organic matter content by 17, 26, 33, and 46%, respectively (Table 2).

Small grain crops (such as rye) are good hosts or trap crops for southern root-knot and Columbia lance nematodes. In 2015, the cover crop system helped to reduce population densities of root-knot nematodes by 66% and 82% in tilled and no-till plots, respectively. In addition, galling index for the same treatments was reduced by 34% in tilled plots and 31% in no-till plots without a nematicide application.

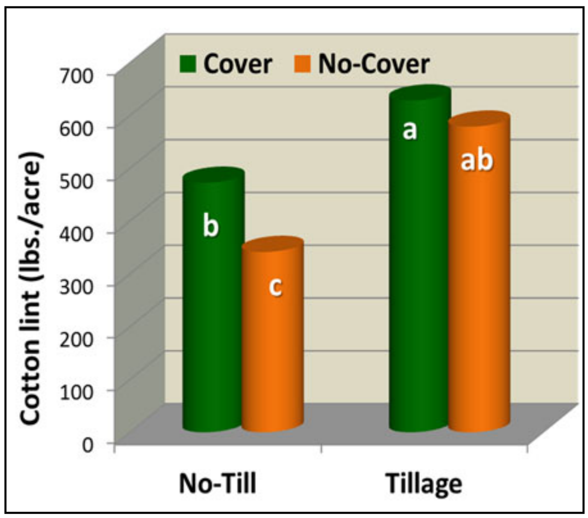

Figure 5. Effects of cover crop and tillage on cotton lint.

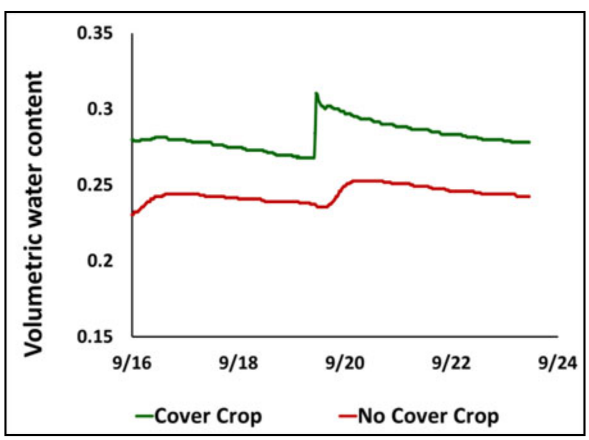

Figure 6. Effects of cover crop on soil moisture content.

Table 2. Effects of cover crop on available P, K, Mn and soil OM (2014).

	Tillage		No-Till	
	Cover	**No-Cover**	**Cover**	**No-Cover**
P (lbs./acre)	235 a	191 b	220 a	188 b
K (lbs./acre)	173 a	119 b	149 a	116 b
Mn (lbs./acre)	29 a	22 b	28 a	21 b
OM (%)	1.41 a	0.87 b	1.42 a	0.97 b

Summary

Replicated field studies were conducted for two years with three different soil types to determine the effects of cover crops on soil chemical and physical properties, crop responses, and pest pressure. Results showed that the soil texture had a significant effect on the amount of cover crop biomass. In no-till plots, cover-crop significantly reduced soil compaction in the E-horizon (10-15 in depth). Averaged over the entire field, the cone index values in cover crop plots were below the 300 psi level measured at the end of the production season. Reductions in soil compaction due to cover crop, significantly increased cotton lint yield in the no-till plots (38%). There was a strong linear correlation between cover crop biomass and cotton lint yield increase. The cover crop positively impacted soil properties by significantly increasing available P, K, Mn, and organic matter content. It also, increased soil moisture content by about 10 percentage points. In 2015, the cover crop significantly reduced population densities and galling index of root-knot nematodes without a nematicide application.

Acknowledgements

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