EFFECTS OF PERENNIAL GRASSES ON SOIL QUALITY INDICATORS IN COTTON AND PEANUT ROTATIONS IN VIRGINIA

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INTRODUCTION

Crop rotation has long been recognized as an important cultural practice for sustaining soil quality, economic stability and yields (Bullock, 1992). Rotations of continuous row crops such as corn and soybean are common in farming systems of the Southeast, particularly utilizing no-till and minimum tillage strategies with cover crops planted to reduce soil erosion and increase organic matter (Wright et al., 2002). Winter cover crops, though effective in reducing soil loss through wind and water erosion, offer little to no over all soil improvement due to their short duration in the field (Wright et al., 2002). Incorporation of perennial grasses into traditional row crop rotations may enhance economic and environmental returns. Potential environmental benefits of perennial grasses include enhanced soil carbon sequestration, soil stabilization and decreased nutrient loss (Bullock, 1992). Potential benefits to the producer are increased yield in row crops following perennial grasses through soil enhancement with minimal purchased inputs as well as a more economically stable system when livestock is included (Siri-Prieto et al., 2002, Prechac et al., 2002).

While carbon dioxide is the fundamental gas from which dry matter is built through photosynthesis and the Calvin cycle, its increasing atmospheric concentration through the burning of fossil fuels and other natural means contributes to the warming of the planet through the greenhouse effect (Mosier et al., 2005). Agricultural practices can alter this increasing greenhouse gas concentration. Soil that is constantly disturbed can act as a source of carbon dioxide through the respiration of organic carbon by soil microbes, while undisturbed soils may act as a sink for carbon (Gebhert et al., 1994, Al-Kaisi et al., 2005). Soils planted to perennial grasses that are undisturbed for several seasons are potential carbon sinks because the grass crops are adding organic matter to soils through root growth, and organic matter decomposition is reduced by not tilling the soil (Paustian et al., 1997, Conant et al., 2001, Gentile et al., 2005). Further, soils that have been depleted by continuous row crop agriculture utilizing tillage, such as those historically in peanut and cotton rotations, that are placed into perennial grasses offer large potential as carbon sinks (Paustian et al., 1997). In a review of published data, all but one of the cultivated crop lands converted into perennial grass pastures showed an increase in soil carbon (Conant et al., 2001). This data reflected an average yearly increase over 3% C concentration or 1,010 kg $C \cdot ha^{-1} \cdot yr^{-1}$ by mass over a 23-year sampling period for cultivated land converted to well managed pasture. This can be attributed to the minimal disturbance of soil under perennial grass, as well as the extensive root system of perennial grass crops which can increase potential for subsoil carbon sequestration (Gentile et al., 2005).

A review of a series of cropping systems experiments in Uruguay by Prechac et al. (2002) presents data that displays a trend for soil carbon content to increase to a maximum after

4 years in perennial grass, at which point row crops begin drawing down carbon pools until perennials are rotated back in. This is in comparison to a continuous cropping system that continually decreased the soil carbon pool over the 26-year period of the experiment. This data set illustrates the potential for a sustainable soil carbon pool when perennial grasses are utilized in rotation with row crops.

Irrigation of cotton and peanuts in the Virginia peanut production region is an exception due to the lack of easily available irrigation water sources. Producers typically rely on stored soil moisture from the winter and rain fall events during the growing season. When rooting is limited to the dominantly sandy upper horizons of the soil profile where available soil moisture retention is low, growing season rainfall events are the major source of crop moisture.

Row crops that follow perennial grasses in rotation may experience less drought stress than those in continuous row cropping. There are several mechanisms which may create this effect. First, perennial grasses have the potential to grow deep roots over several seasons. This allows roots of perennial grasses to grow through restrictive plow layers creating channels in plow pans for roots of subsequent row crops to reach greater depths for moisture and nutrients (Prechac et al., 2002). This allows row crops to access greater volumes of soil and available water. Further, the lower horizons that are often restrictive to root growth tend to have a higher clay content and water holding capacity (Wright et al., 2002). Perennial grass crops can increase soil organic matter and evidence indicates that increases in soil organic matter are tied directly to increases in available water between field capacity and the permanent wilting point. According to B.D. Hudson (1994), an increase in soil organic matter by mass from 1 to 3% would double the plant available water across diverse soil types. Increasing plant available water is of particular importance in Virginia cotton and peanut production where irrigation is rare and rainfall is relied upon. Greater rooting depth along with greater soil moisture allows for fewer drought days and greater access to nutrients allowing for more vigorous above ground growth often reflected in measurements such as leaf area index, plant height, and yield (Pettigrew 2004, Katsvairo et al., 2006).

The overall objective of this project was to determine if production of perennial grass crops in selected crop rotations with cotton and peanuts will improve the sustainability of crop production on typical southeastern Virginia soils.
Specific objectives are:

1. Measure changes in soil quality parameters such as organic matter, bulk density, resistance to root penetration, moisture holding capacity and water infiltration rate in crop rotations with and without perennial grasses.
2. Measure the influence of crop rotations with and without forage crops on the overall yield and quality of cotton and peanuts.

The latter objective will not be discussed in this paper.

Materials and Methods

The study was conducted at the Tidewater Agricultural Research and Extension Center. Eight crop rotations were selected for study and are shown in Table 1. The rotations were arranged in a Randomized Complete Block Design with four replications. Plots were 8-rows (7.38 m, 24 ft) wide by 12.3 m (40 ft) long. Thirty foot alleyways were established between blocks for maneuvering equipment. The experiment was located on a Nansemond fine loamy sand soil series (Coarse-Loamy, Siliceous, Subactive, Thermic Aquic Hapludults).

Table 1. Eight crop rotations selected for study and the sequence of crops in each rotation for the years 2003-2007.

Rotation	2003	2004	2005	2006	2007
1	Peanut	Cotton	Cotton	Cotton	Cotton
2	Peanut	Cotton	Corn	Cotton	Peanut
3	Peanut	Cotton	Peanut	Cotton	Peanut
4	Peanut	Tall fescue	Tall fescue	Cotton	Peanut
5	Peanut	Orchardgrass	Orchardgrass	Cotton	Peanut
6	Peanut	Tall fescue	Tall fescue	Tall fescue	Peanut
7	Peanut	Orchardgrass	Orchardgrass	Orchardgrass	Peanut
8	Peanut	soybean	Cotton	Cotton	Peanut

*follow all row crops after 2005 with wheat cover after row crop harvest and until spring planting

Plots were sampled for intact soil cores using 2 inch copper pipe segments with two inch diameters, taped end to end to a length of 6 inches. In two locations in each plot, the pipe was driven into the soil using a rubber mallet. Soil cores were then excavated and sliced into 2 inch segments. Measurements of water holding capacity (WHC) were made on the upper 2 inch segment and lower 2 inch segment of each intact core. The middle sections were discarded as availability of copper rings required the reuse of the center section. Cores were saturated for 24 hrs and weighed. Water holding capacity was measured using pressure pots equilibrated to 1/3 bar (field capacity), 1 bar, or 15 bars (permanent wilting point). After each equilibration period (4 days, 1 week, and 2 weeks respectively) cores were weighed and re-saturated. After the final equilibration at 15 bars, cores were dried and weighed to determine the total water held at each pressure as well as bulk density of the soil in each core.

Saturated infiltration measurements were made August 4 through 8, 2006 using three double ring Turf-Tech infiltrometers. Six total runs were made per plot only in row middles which had not experienced wheel traffic. The time to infiltrate a 5 cm column of water was recorded with a subsequent recording of the time for the same column to infiltrate 8 cm. The difference in these two times provided a relative measure of the saturated infiltration. Bulk density samples were taken simultaneously with infiltrations using 6” copper cylinders with a 2” diameter driven into the soil, then removed and sealed with plastic wrap. Samples were weighed for a wet weight and then dried at 105^{o} C for 24 hours then weighed again. These samples in addition to bulk density provided soil moisture contents at the time of the infiltrometer runs.

Soil resistance to penetration was used to determine depth to any root growth restrictive zones in the profile. All plots will be evaluated to see if depths to root restrictive zones are associated with treatment effects. A Field Scout SC 900 data-logging Soil Compaction Meter will be used to sample resistance with at least 6 readings taken between crop rows. Samples will be taken during the season following adequate rainfall when soil is near field capacity in order to eliminate differences in soil resistance associated with moisture status. If adequate rainfall does not occur in a given season, irrigation may be employed to bring soil to field capacity for sampling of resistance to penetration.

Soil samples will be collected in April and August from the 6 inch surface layer of each plot. Twenty cores will be taken from each plot using a soil probe, homogenized and tested for pH, fertility levels and organic carbon content. Samples will be processed by the Virginia Tech Soil Testing Lab for available pH, P, K, Ca, Mg, and organic matter content by loss upon ignition. Changes in organic matter content due to rotation effects will also be assessed using carbon and nitrogen content and ratio with a carbon-nitrogen analyzer. Soils will be sampled from 0-3" and 3-6" for carbon-nitrogen content.

RESULTS

No statistically significant differences were found between treatments in measurements of saturated water infiltration, soil moisture at the time of the measurements, or bulk density.

Statistical analysis has not been conducted on data from soil resistance to penetration measurements. Observation of the data set however indicates that resistance to root penetration is reduced after two years of perennial grasses. The data reported below indicates that cotton following fescue or orchardgrass does not experience a 3000 kPa resistance and would therefore root growth would not be restricted physically. All other rotations reached a limiting resistance by 32 cm with the shallowest restrictive layer in cotton-peanut-cotton-peanut rotations at 25 cm. Resistance curves are shown below in figure 1.

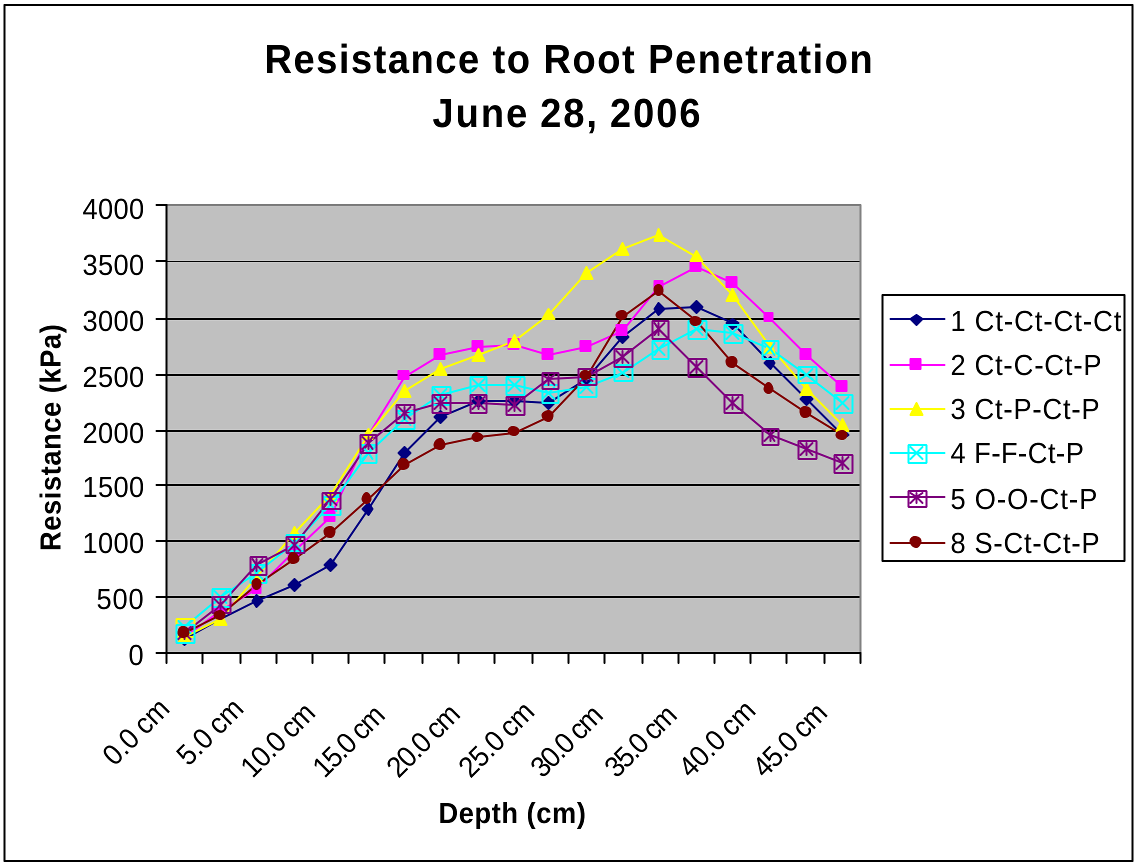

Figure 1: Soil resistance to penetration as measured by a data logging penetrometer on the 28th of June.

No significant difference was found in available water content at either the 0-2" (table 1a) depth or 4-6" (table 1b) depth.

Water content of intact soil core at a depth of 0-2 in.				
	mg water per liter soil			
Treatment	**0 bar**	**1/3 bar**	**1 bar**	**15 bar**
Ct-Ct-Ct-P	16.147 a	5.485 a	4.861 a	4.086 a
Ct-C-Ct-P	15.464 a	5.614 a	4.965 a	4.232 a
Ct-P-Ct-P	14.952 a	4.656 a	4.087 a	3.469 a
F-F-Ct-P	16.096 a	4.602 a	4.015 a	3.377 a
O-O-Ct-P	15.857a	5.606 a	4.960 a	3.989 a
S-Ct-Ct-P	16.017 a	4.816 a	4.257 a	3.711 a

Table 1a: Water content of intact soil core at depth 0-2 inches over drying regimes. Means followed by the same letter do not significantly differ (P=0.05, LSD)

Water content of intact soil core at a depth of 2-4 in.				
	mg water per liter soil			
Treatment	**0 bar**	**1/3 bar**	**1 bar**	**15 bar**

Ct-Ct-Ct-P	**12.928 a**	**5.596 a**	**4.977 a**	**4.150 a**
Ct-C-Ct-P	**13.052 a**	**5.147 a**	**4.437 a**	**3.565 a**
Ct-P-Ct-P	**12.605 a**	**4.897 a**	**4.247 a**	**3.598 a**
F-F-Ct-P	**12.736 a**	**5.234 a**	**4.553 a**	**3.614 a**
O-O-Ct-P	**12.791a**	**5.212 a**	**4.564 a**	**3.737 a**
S-Ct-Ct-P	**12.999 a**	**5.084 a**	**4.431 a**	**3.806 a**

Table 1b: Water content of intact soil cores at depth 4-6 inches over drying regimes.
Means followed by the same letter do not significantly differ (P=0.05, LSD)

Soil carbon and nitrogen content by weight per volume of soil was statistically the same across all treatments at both a depth of 0-3 inches (table 2a) and 3-6 inches (table 2b). Carbon to nitrogen ratio was also statistically the same across all treatments.

	Carbon and Nitrogen Data, 0-3 inches		
Treatment	**mg N / L soil**	**mg C / L soil**	**C / N ratio**
Ct-Ct-Ct-Ct	**101.5 a**	**1014.5 a**	**9.8 a**
Ct-C-Ct-P	**92.2 a**	**909.4 a**	**9.8 a**
Ct-P-Ct-P	**84.5 a**	**740.8 a**	**8.8 a**
F-F-Ct-P	**89.2 a**	**765.5 a**	**8.6 a**
O-O-Ct-P	**67.9 a**	**562.0 a**	**8.3 a**
S-Ct-Ct-P	**87.8 a**	**740.2 a**	**8.4 a**

Table 2a: Carbon and Nitrogen content at a depth of 0-3 inches.
Means followed by the same letter do not significantly differ (P=0.05, LSD)

	Carbon and Nitrogen Data, 3-6 inches		
Treatment	**mg N / L soil**	**mg C / L soil**	**C / N ratio**
Ct-Ct-Ct-Ct	**91.2 a**	**902.1 a**	**9.5 a**
Ct-C-Ct-P	**83.4 a**	**832.7 a**	**9.9 a**
Ct-P-Ct-P	**82.4 a**	**695.2 a**	**8.4 a**
F-F-Ct-P	**82.2 a**	**693.1 a**	**8.4 a**
O-O-Ct-P	**75.0 a**	**553.1 a**	**7.4 a**
S-Ct-Ct-P	**81.5 a**	**675.9 a**	**8.3 a**

Table 2b: Carbon and Nitrogen content at a depth of 3-6 inches.
Means followed by the same letter do not significantly differ (P=0.05, LSD)

CONCLUSIONS

There was little difference found between treatments in soil quality indicators with the exception of resistance to penetration. However observations of the plots throughout the season would indicate differences which we did not elucidate. Treatments including perennial grass were observed to infiltrate water at a greater rate during actual rain showers. Though not discussed in this paper, yield enhancement was also seen in cotton following perennial grasses compared to other rotations. This may be due to insufficient rain fall during the 2006 growing season. Cotton experiencing lower resistance to root penetration due to inclusion of perennial grass was able to reach soil moisture stored deep in the profile versus shallow depths explored by crops experiencing a hard pan. If this is true yield enhancements may not be seen following perennial grass if there is sufficient rain fall during the season.

In 2007 all rotations with the exception of continuous cotton will be planted to peanut. All of the measurements of soil quality indicators will be taken again. Changes in soil organic matter were hypothesized due to treatment effects however they were not seen. To look more clearly at this, samples will be stratified by the inch to a depth of 6 inches. Also infiltration measurements will be made using an infiltrometer with water rained onto the plot using a Cornell Infiltrometer. This style infiltrometer will also be used to measure aggregate stability. Further pipe collectors will be fabricated to measure water pooling in the plots during actual rain fall events.

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