SOIL-AGGREGATE STABILITY AND LEAF WATER POTENTIAL UNDER CONSERVATION TILLAGE AND SOD-BASED CROP ROTATIONS IN A SEQUENCE OF DRY AND WET YEARS

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ABSTRACT

Perennial grass such as bahiagrass (*Paspalum notatum* Flugge) in rotations with cotton and peanuts under conservation tillage has shown positive impact on crop yields and economics. A long term experiment is in the 9th year at the University of Florida's North Florida Research and Education Center in Quincy to evaluate the impact of short-term perennials (2 yr bahiagrass) in a rotation scheme with peanut and cotton in conservation-till system. The experiment was a split-plot design with three replicates. Irrigation regime was the main plot and cropping system was subplot. Under irrigated conditions, peanut in sod-based system had significantly higher yields than the conventional peanut, but cotton yield response to cropping system depended on years; under non-irrigated conditions, both cotton and peanut in the sod-based cropping system had higher yields. Therefore, especially under non-irrigated condition, sod-based cropping system mitigated water deficit stress effect on crops and improved crop yield and water use efficiency compared to the conventional cropping system.

INTRODUCTION

The classical concepts of crop rotations are related to the technology of soil cultivation, pests control and water/nutrient supply. Advances in plant genetics and agronomic engineering, as well as the relatively cheap energy sources have resulted in a shift to specialization and concentration that appears to impair soil resilience, nutrients cycling, and agricultural stability (Gates, 2003; Franzluebbers, 2007). Some challenges to an economically viable and sustainable farming system are infertile soils, crop protection, low soil organic matter, and low soil water holding capacity. It is estimated that up to 80 per cent of the farming in the Southeastern US Coastal Plains is high input management (irrigation, fertilizers, and pesticides) of peanut-cotton rotation. Thus, there is still a need for estimating a balance that has to be maintained between agricultural production and environmental protection. A series of studies begun in 1999 at the University of Florida's North Florida Research and Education Center (NFREC) in Quincy, aiming to address these challenges by integration of perennial grasses into conservation-till rotation system of peanut and cotton (Katsvairo et al., 2007; Wright et al., 2007). Many aspects of the system have been and are being studied. Integrating perennial grasses, such as bahiagrass (*Paspalum notatum* Flugge) into the system has shown positive impacts on crop yield and economics. Short-term (2 yr) perennials in the rotation adds significantly to the soil organic carbon and nitrogen pools as well as helps diminish nematodes and other pests normally found with annual row crops (Tsigbey et al, 2009). Rearrangement of soil-inherited and external-stimulated processes often occurs in soils but the effect of different loading rate of conservation-till system with short-term (2 yr) bahiagrass on soil aggregates and leaf water potential (LWP) is

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rarely discussed. In this paper we address the impact of different row-crop to sod-grass sequences on soil aggregation and cotton LWP under conventional and sod-based rotation in a dry-wet-year sequence.

MATERIALS AND METHODS

A crop-rotation experiment was established to study two cropping systems (sod-based vs. conventional) under two irrigation regimes (irrigated vs. non-irrigated) and conservation tillage on a Dothan sandy loam at the University of Florida's North Florida Research and Education Center in Quincy, FL. The sod-based system is a 4-yr rotation with bahia-bahia-peanut-cotton, while the conventional system is a 3-yr rotation with peanut-cotton-cotton. In both systems a winter oat cover crop is following the summer crops. The irrigated plots are irrigated with a lateral-moving irrigation system when needed, whereas the non-irrigated plots have never received any irrigation since the experiment started in 2000. During 2000–2006 period the irrigation was applied based on Florida cotton production guidelines. In 2007 and 2008 the irrigation was applied when lowest LWP was about -15 bars during squaring and fruiting (Zhao and Oosterhuis, 1997).

Three weeks prior to cotton planting, oat cover crop was killed with Roundup and plot rows were strip-tilled using a Brown Ro-till implement. Cotton cultivar ‘DP 555 BG/RR’ was used for this study. All plantings were made in early May using a Monosem pneumatic planter with a row spacing of 3 feet and about 4.5 seeds per foot row. Nitrogen (25 lbs. N acre^{-1}), P (50 lbs. P acre^{-1}), and K (75 lbs. K acre^{-1}) from a combination fertilizer (5-10-15) were band applied adjacent to each row at planting. Cotton was sidedressed with additional N of 60 lbs. acre^{-1} (ammonia nitrate) at first square stage. Seedcotton was mechanically harvested from four middle rows in each plot two weeks after defoliation for determination of seedcotton yield. Two seedcotton subsamples (2 lbs each) in each plot were ginned to determine turnout (lint %). Lint yield was estimated based on seedcotton yield and lint %.

Peanut (cv. ‘Georgia Green’ or ‘AP-3’) was planted at 8 seeds per foot row in mid May. Peanuts were dug in mid September to early October. When peanut reached maturity stage, the four middle rows in each plot were mechanically dug and inverted prior to harvest. Pod samples were placed in a forced-air dryer at 113°F for 72 hours to ensure for a constant weight. Pod yield were determined.

During the 2007-2008 growing season, LWP of uppermost fully expanded leaves was measured with a plant water status console (Soil Moisture Inc., CA); the same procedure was also used for the oat winter-cover crop.

In the early spring of 2009 soil-aggregate separation was made from 0 to 20-cm depths with a 5-cm increment in a range (0-100%) of sod-based crop rotations; five aggregate-size ranges (2, 2-1, 1-0.5, 0.5-0.25, and 0.25-0.053 mm) were obtained by sieving.

The experiment was a set up as a completely randomized design with 3 replications. Irrigation was the main plot and crop rotation was the sub-plot. Plots received irrigation water according to standard extension recommendations for production in Florida. Weed and other crop management practices were done based on the Florida Cooperative Extension Services recommendations. All data were evaluated with the MIXED procedure in SAS (SAS, 2002).

RESULTS

Precipitation and irrigation during the experimental years

Cumulative yearly and seasonal precipitation during both major-summer (May-October) and cover-winter (November-April) growing seasons are presented in Table2/Fig. 1. The annual mean precipitation for the 2002 and 2003 (51.3 and 51.5 inches respectively) was close to the 30-yr average of 50.1 inch; for May-October growing season these two years were close to the 30-inch normal with precipitation of 25.5 and 35.5 inches, respectively. The 2004 and 2005 growing seasons were wet with up to 7 inches more precipitation from the long-term average of 30.0 inches, while the 2006 and 2007 growing seasons were dry (26.6 and 21.5 inches respectively. This wide range of hydrological years during the experiment allows us to analyze conservation tillage and rotational system responses to irrigation. The amount of irrigation for the 2002-2008 growing seasons for the study ranged from 4.2 to 7.6 inches (Table 1).

Table 1

Accumulated precipitation and amount of irrigation in the 2002 to 2007 growing seasons from April to October at Quincy, FL

Year	2002	2003	2004	2005	2006	2007	2008
	-------------------------------------- (inch) --------------------------------------						
Precipitation	25.5	35.5	36.9	31.8	26.6.2	21.5	32.6
Irrigation	7.4	4.4	5.0	7.5	7.6	5.2	4.2
Year type	Normal	Normal	Wet	Wet	Dry	Dry	Wet

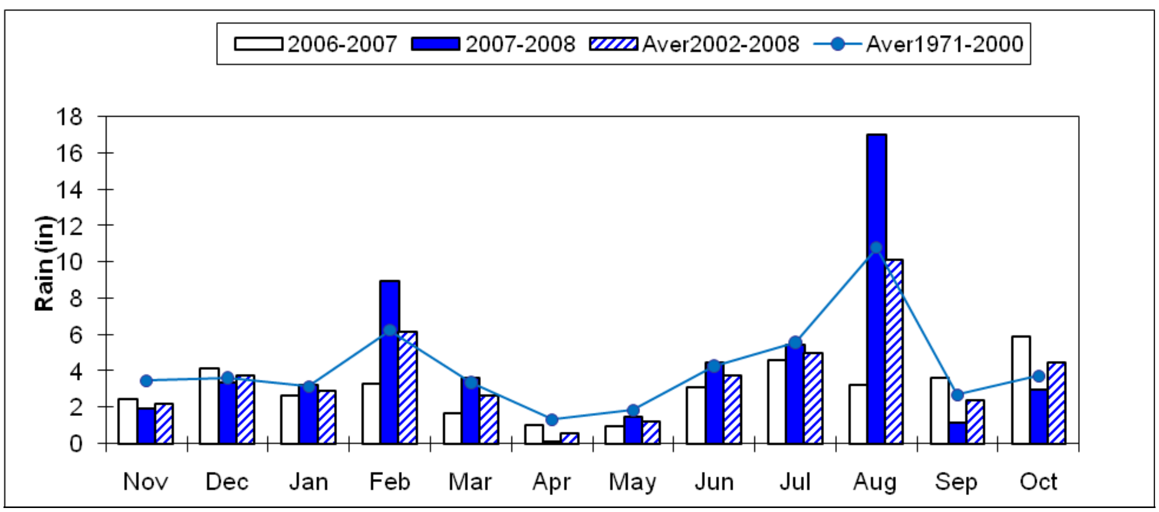


Figure 1

Monthly climatic water balance of the sod-based trial in Quincy, FL

Table 2
Precipitation (inch) during the 2006-2007 and 2007-2008 hydrological years in a comparison with short (6-yr) and long (30-yr) averages for Quincy, FL

Hydrological year	May-October	November-April	Year-total
2006-2007	21.54	15.27	36.81
2007-2008	32.64	21.34	53.98
Average 2002-2008	27.09	18.31	45.40
Average 1971-2000	28.92	21.20	50.12

Soil aggregates
Perennial sod has an effect on soil aggregation, but the proportion of the sod in a crop rotation may affect the quantification of aggregate size distribution. The mean weight diameter (MWD) of the aggregates was calculated and correlated with the soil properties; the smaller the aggregate, the higher was the aggregate stability. The aggregate-size status differed between crop-rotation systems as well as between the top two depths (0-5 and 5-10 cm) within a system; no significant differences were observed below 6-in depth. In spite of conservation tillage the permanent sod and the rotations without sod decreased in aggregate stability compared with the sod-based rotations (Fig. 2).

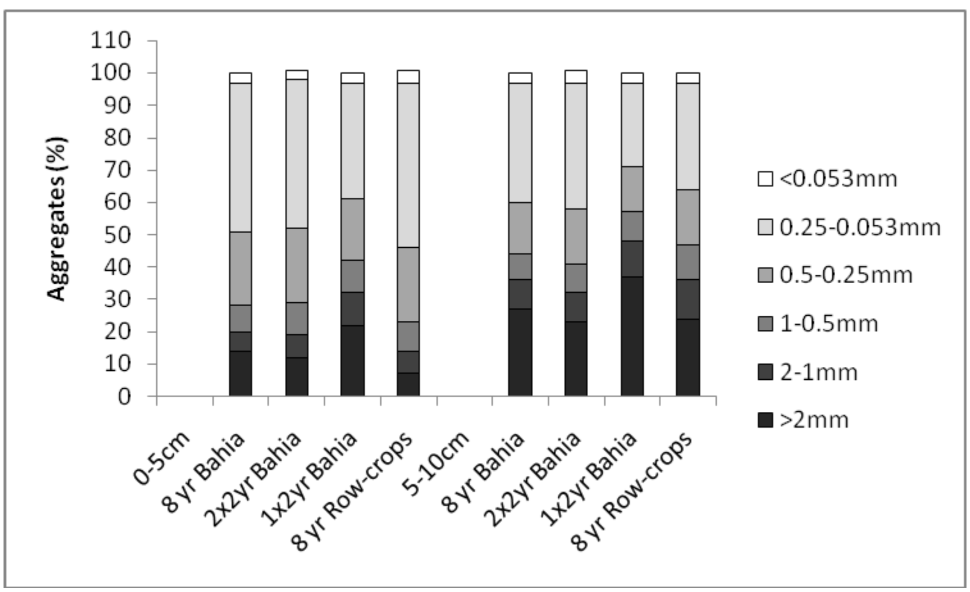


Figure 2
Particle-size distribution in the top 2 soil layers of the sod-based trial in Quincy, FL

Leaf water potential
In general, both peanut and cotton grown in the sod-based cropping system had greater LWP than plants grown in the conventional system, especially under non-irrigated conditions. During the 2007 growing season, the mean LWP values of sod-based and conventional peanuts were -4.9 and -8.3 bars, respectively, under irrigated conditions and -8.3 and -16.2 bars, respectively,

under non-irrigated conditions. Similarly, LWP of sod-based and conventional cotton were -14.1 and -14.6 bars, respectively, under irrigated conditions and -15.9 and -17.5 bars, respectively, under non-irrigated conditions (Data not shown). Integrating cover crops into rotations have also shown to benefit soil quality and productivity. In the 8-yr crop-rotation study the leaf water potential (LWP) was measured during both summer 2008 and winter 2008-2009 to assess plant response of both major and cover crops to moisture stress. According to the measurements sod-based cotton had -13.8 bars mean LWP while conventional (1st and 2nd year) crops with the -15.4 and 15.2 bars were also in the range of well-watered plants (Fig. 3).

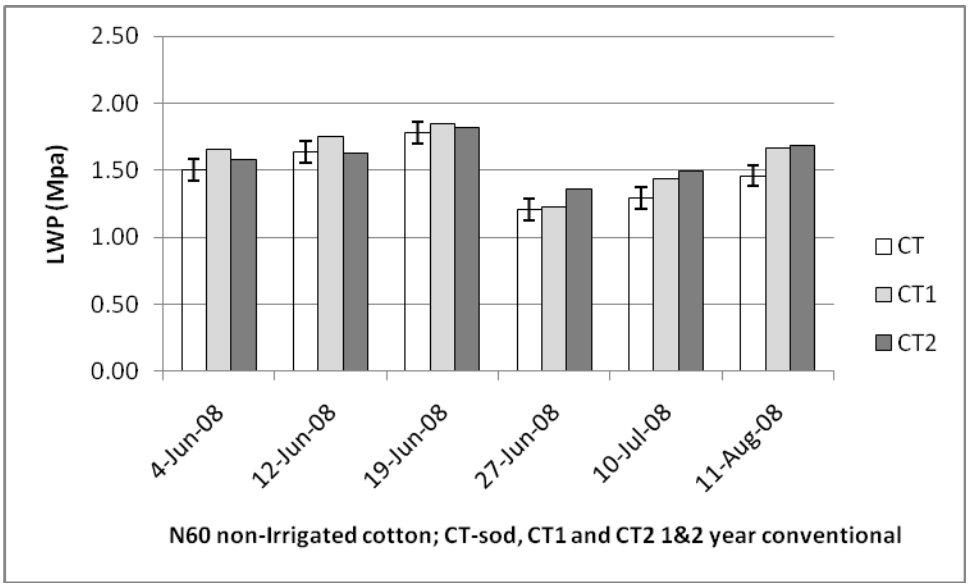
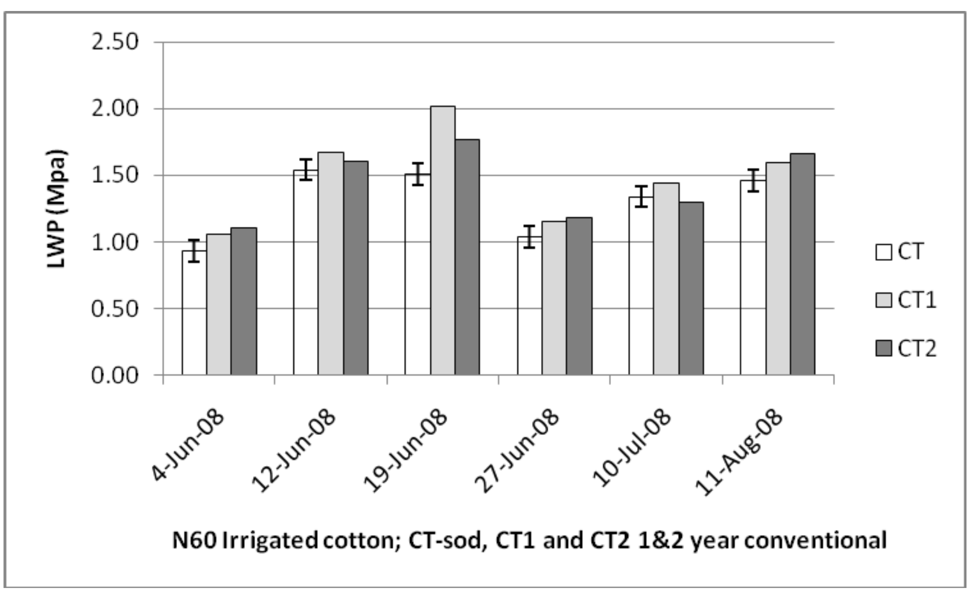


Figure 3. Dinamic of cotton-LWP during 2008 groing season



Similar tendency was observed for the following oat-cover crop; -14.7 bars LWP was detected after 2nd year cotton vs. -10.2 bars after sod-based cotton and -11.3 bars for the oats following 1st year cotton (Fig. 4). The same trends for lower LWP in sod-based systems were seen in both major (peanut) and cover (oat) crops.

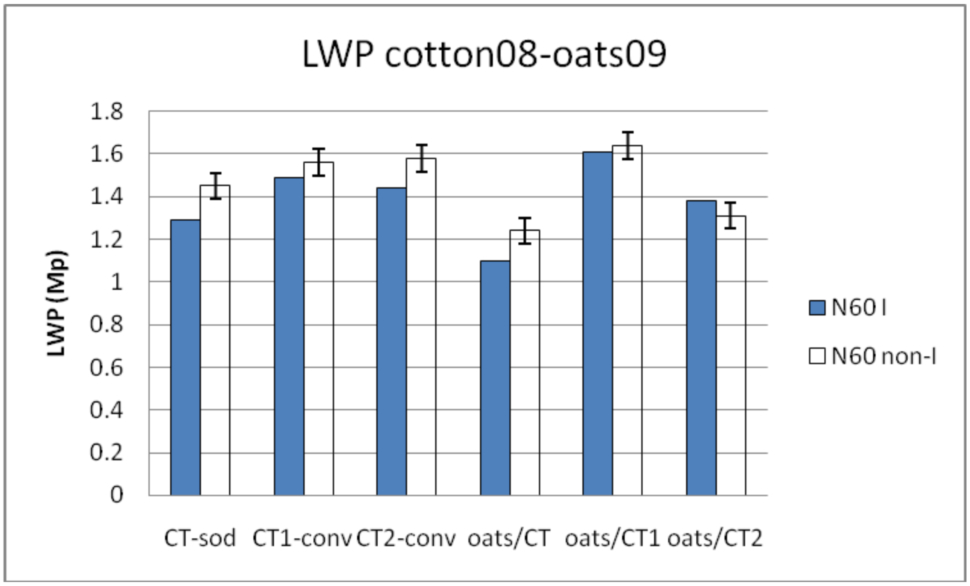
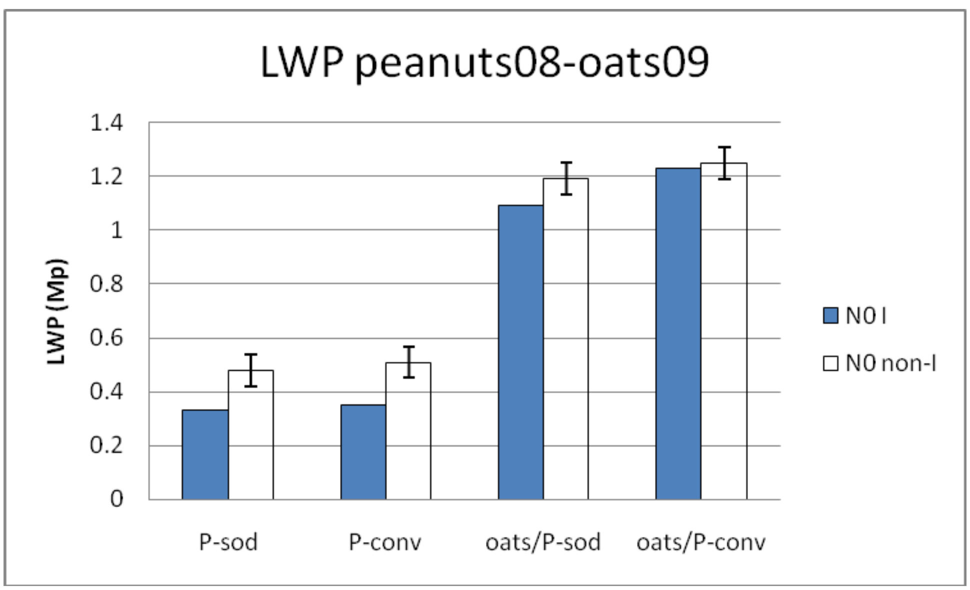


Figure 4
LWP means of both major summer and cover winter crops



CONCLUSION

The results of this study indicated that irrigation in both sod-based and conventional cropping systems with winter oat cover crop and a wide range of precipitation/irrigation water did not improve either peanut or cotton yields in normal years in the southeast USA. However, the row crops in the sod-based system are responding better to water stress in both dry and wet years. Even in dry years, there is potential to reduce irrigation, conserve regional water, and improve crop water and nutrients use efficiency. Compared to conventional system, sod-based peanut-cotton rotation can improve soil quality and crop growth resulting in higher crop yields, water-nutrients use efficiency and overall profitability.

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