Yield and Water Use Efficiency of Cotton and Peanut in Conventional and Sod-Based Cropping Systems

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Abstract

An experiment was conducted at the North Florida Research and Education Center, Quincy, FL to determine cotton and peanut plant water status, yield and water use efficiency of conventional (peanut-cotton-cotton) and sod-based (bahiagrass-bahiagrass-peanut-cotton) cropping systems under irrigated and non-irrigated conditions. 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 significant higher yield 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 leaf water potential and higher yields compared with conventional cropping system. 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

Studies have shown that sod-based rotation of peanut and cotton in the southeast US can significantly reduce disease pressure (Dickson and Hewlett, 1989; Johnson et al., 1999; Marois and Wright, 2003), improve crop growth, and increase crop yield and profits (Brenneman et al., 1995; Katsvairo et al., 2006) compared with conventional cropping systems. In this report, we determined yields and water use efficiencies of irrigated and non-irrigated peanut and cotton in sod-based and conventional systems.

Materials and Methods

A crop rotation study was initiated in 2000 at the University of Florida's North Florida Research and Education Center in Quincy, FL. The soil type at the experimental location is Dothan sandy loam. Treatments included two cropping systems (sod-based and conventional peanut/cotton rotations) and two irrigation regimes (irrigated and non-irrigated). The sod-based system was a 4-yr rotation with bahiagrass-bahiagrass-peanut-cotton and the conventional system was a 3-yr rotation with peanut-cotton-cotton. Both systems used conservation tillage (strip-till for summer crops) with winter oat cover crop following the summer crops. The non-irrigated plots never received any irrigation during the experiment. The irrigated plots were irrigated using a lateral move irrigation system if needed. In 2000–2006, irrigation was applied based on Florida cotton production guidelines. In 2007, irrigation was applied when lowest leaf water potential was approximately -15 bars during squaring and fruiting (Zhao and Oosterhuis, 1997).

The second year bahiagrass in the sod-based rotation was killed in late Oct. of each year with 3 qts. of Roundup Weather Max per acre for the coming year peanut. In late March of each year, about 3 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 458 BG’ (2002-2004) or

‘DP 555 BG/RR’ (2005-2007) was used for this long-term rotation study. All plantings were made from late April to 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. Peanut (cv. ‘Georgia Green’ or ‘AP-3’) was planted at 8 seeds per foot row in mid to late May. Peanuts were dug in mid-Sept. to early Oct. Details of bahiagrass and peanut management and other cotton crop management practices were done according to standard University of Florida crop production recommendations.

During the 2007 growing season, lowest leaf water potential (LWP) of uppermost fully expanded leaves was measured with a plant water status console (Soil Moisture Inc., CA). 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 %. 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 and weighed. Pod yield were determined based on the sample dry weight. Crop water used efficiency (WUE) was estimated using crop yield dividing by the sum of precipitation and amount of irrigation during the growing season from April to Sept.

The experiment was a split-block design with 3 replications. Irrigation was the main plot and crop rotation was the sub-plot. The sub-plot size was 80 × 60 feet with 20 rows in each plot. All data were analyzed for variances using the GLM procedures and Fisher LSD tests were employed to separate mean differences between irrigation treatments or cropping systems (SAS Inc., 2002).

Results and Discussion

Precipitation and irrigation during the experimental years

Cumulative precipitation and amount of irrigation for irrigated treatments during growing seasons in this study are presented in Table 1. Overall, the 2002 and 2003 growing seasons were close to normal with precipitation of 25.2 and 28.7 inches, respectively; the 2004 and 2005 growing seasons were wet with 6.4 to 6.7 inches more precipitation compared to long-term average (30.0 inches); and the 2006 and 2007 growing seasons were dry. Especially the 2007 was extremely dry with only 51% of normal precipitation from Apr. to Sept. (Table 1). The wide range of precipitation during the experiment allows us to analyze crop WUE and yield responses to irrigation. Amount of irrigation in the 2002 to 2007 growing seasons for the study ranged from 4.4 to 7.6 inches (Table 1).

Table 1. Accumulated precipitation and amount of irrigation in the 2002 to 2007 growing seasons from April to September at Quincy, FL.

Year	2002	2003	2004	2005	2006	2007	Long-term
	----------	----------	----------	(inch)	----------	----------	----------
Precipitation	25.2	28.7	36.3	36.7	17.2	15.4	30.0
Irrigation	7.4	4.4	5.0	7.5	7.6	5.1	---
Year type	Normal	Normal	Wet	Wet	Dry	Dry	---

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 (Data not shown). 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.

Yields

Pod yields did not differ between irrigated and non-irrigated peanuts, except for conventional peanut in 2007 which was an extremely dry year with a significantly lower yield for non-irrigated peanut in the conventional system (Table 2). Averaged across years and the cropping systems, yields of the irrigated and non-irrigated peanuts were 3228 and 3125 lbs. acre^{-1}, respectively. Peanut yield varied among years and ranged from 2146 to 4342 lbs. acre^{-1}. In most years, sod-based peanut had significantly higher yield than conventional peanut, except for 2002 in which yield did not differ between the two cropping systems. Averaged across years and irrigation regimes, the sod-based peanut (3464 lbs acre^{-1}) had a 20% ($P < 0.01$) higher yield than the conventional peanut (2889 lbs acre^{-1}, Table 2).

Table 2. Peanut pod yield response to the sod-based and conventional cropping systems under irrigated (Irr.) and non-irrigated (Non-irr.) conditions in Quincy, FL.

Year	Sod-based			Conventional		
	Irr.	Non-irr.	Mean	Irr.	Non-irr.	Mean
	---------------------------- (lbs. acre^{-1}) ----------------------------					
2002	3245	3360	3302	3300	3014	3157
2003	2829	2737	2783	2197	1719	1958
2004	3282	3287	3284	2245	2584	2414
2005	3041	2780	2911	2142	2150	2146
2006	4154	4165	4159	3492	3590	3541
2007	4423	4261	4342	4382*	3854	4118
Mean by Irr.	3496	3432		2960	2818	
Mean by system	3464**			2889		

* and ** indicate that differences between Irr. And Non-irr. Within a year or between the two systems are significant at $P \leq 0.05$ and $P \leq 0.01$, respectively.

Lint yields of the sod-based cotton in 2002 (both irrigated and non-irrigated) and 2007 (irrigated) were significantly higher than that of the conventional cotton. There was no statistical difference between the two cropping systems in cotton yields in other years. Averaged across years and irrigation regimes, lint yields of the sod-based and conventional cotton were 1109 and 1026 lbs. acre^{-1} (Table 3). Year and irrigation significantly affected lint yield with $P < 0.0001$ and 0.01, respectively and their interaction effect on lint yield was also significant ($P < 0.01$). Among the six experimental years, lint yield ranged from 751 to 1530 lbs. acre^{-1} for irrigated cotton and from 641 to 1501 lbs. acre^{-1} for non-irrigated cotton (Table 3). Lint yields in 2002, 2003 and 2004 were significantly lower than those in other years for both irrigated and non-irrigated cotton

($P < 0.05 – 0.01$). Irrigation only improved lint yield in dry years of 2006 and 2007 (Table 3). These results indicate that irrigation may not always be necessary for cotton production in the southeast USA.

Table 3. Cotton lint yield response to the sod-based and conventional cropping systems under irrigated (Irr.) and non-irrigated (Non-irr.) conditions in Quincy, FL.

Year	Sod-based			Conventional		
	Irr.	Non-irr.	Mean	Irr.	Non-irr.	Mean
	------------------------------ (lbs. $acre^{-1}$) ---------------------------------					
2002	929	946	938	666	641	653
2003	751	769	760	784	847	816
2004	774	828	801	735	767	751
2005	1530	1505	1518	1373	1436	1404
2006	1462*	1285	1373	1448*	1286	1367
2007	1513*	1021	1267	1303*	1024	1164
Mean by Irr.	1160	1059		1052	1000	
Mean by system	1109			1026		

Although irrigation is necessary for high yield in dry years, it is possible to use less irrigation water to reach yield goals and thus reduce production cost in the southeast. For instance, in 2007, an extremely dry year, irrigation was scheduled based on LWP. When lowest LWP of cotton dropped to -15 bars, irrigation was provided in the irrigated plots. Compared to 2006 (also a dry year), 2007 had 1.8 inches less precipitation and 2.5 inches less irrigation (Table 1) during the growing season, but lint yield of irrigated cotton was equivalent (Table 3). Therefore, there is a great potential to reduce the amount of irrigation and to improve crop production profits even in dry years.

Water use efficiency

Peanut WUE varied greatly among years, depending on precipitation, irrigation, and crop yield (Data not shown). Averaged across years, non-irrigated peanut in sod-based system had the greatest, while irrigated peanut in conventional system had the least WUE. The sod-based peanut had significantly greater WUE compared to conventional peanut under both irrigated (increased 15%) and non-irrigated (increased 19%) conditions ($P < 0.01$, Fig. 1 left). The WUE of sod-based cotton was slightly (5 to 11%) higher than that of conventional cotton, but the differences were not statistically significant within an irrigated treatment (Fig. 1 right). Overall, the non-irrigated crops had higher WUE than irrigated crops (Fig. 1).

Conclusions

Results of six-year irrigation and non-irrigation study in sod-based and conventional cropping systems with winter oat cover crop and a wide range of precipitation and amount of irrigation indicated that irrigation in normal years in the southeast USA did not improve either peanut or cotton yield because the long-term precipitation during the growing season is almost equivalent to potential evapotranspiration in the region. Even in dry years, there is great potential to reduce irrigation water, conserve regional water resource, and improve crop WUE and production profits. Compared to conventional system, sod-based peanut/cotton rotation can improve soil quality and other growth environment, resulting in high crop yields and WUE.

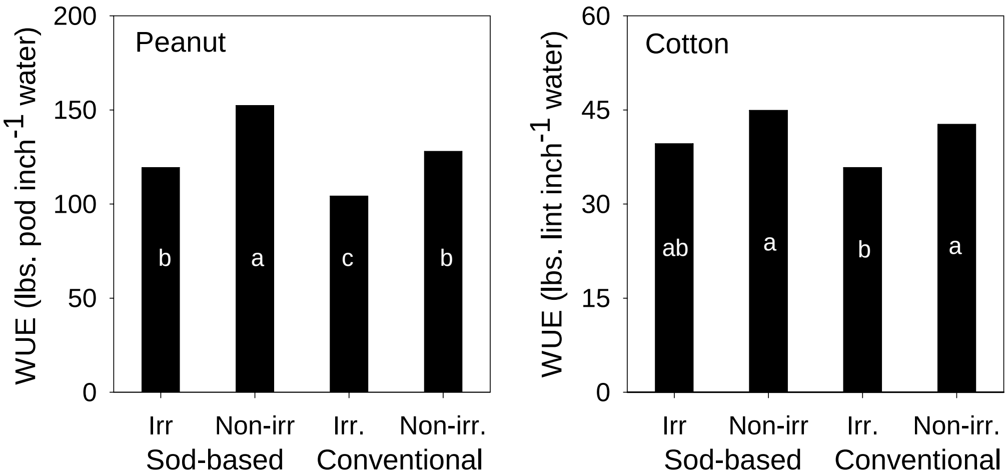

Fig. 1. Water use efficiency (WUE) of sod-based and conventional peanuts and cotton under irrigated and non-irrigated conditions. Data are 6-yr means from 2002 to 2007 in Quincy, FL.

Acknowledgement

This research was supported in part by cooperative research agreements with Cotton Incorporated, USDA-ARS, and Northwest Florida Water Management District. We thank Brian Kidd and all other support staff at the Research Center for their excellent field work and technical assistance.

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