2005 Beltwide Cotton Conferences, New Orleans, Louisiana - January 4 - 7, 2005

INFLUENCE OF BAHIAGRASS ON COTTON ROOTS IN SOD BASED PEANUT/COTTON CROPPING SYSTEMS

Tawainga W. Katsvairo, David L. Wright, James J. Marois and Pawel J. Wiatrak
University of Florida
Quincy, FL

Abstract

Perennial grasses such as bahiagrass (*Paspalum notatum*) included in the peanut/cotton rotation can improve soil conditions and enable superior plant development and growth in the subsequent row crop. It is hypothesized that the roots in subsequent row crops (after perennial grass) are deeper rooted, have a larger surface area and higher N uptake. We measured root biomass, crown root diameter, root length and total root area in bahiagrass/peanut/cotton cropping system and the traditional peanut/cotton cropping system. We also monitored N concentration and uptake for the two cropping systems. In 2003, a wet year, cotton in the sod based rotation had the larger crown root diameter (2.26 vs. 1.63 cm) root area (87.2 vs. 57.4 cm^{-2}) and root length (640 vs. 460 cm) compared to cotton in the peanut /cotton rotation. In the drier year cotton in the sod rotation developed a deeper tap root system. The longer cotton was under bahiagrass, the larger the root biomass, crown root diameter and root length and area. Cotton in the sod rotation had the higher N uptake (226 vs. 144 kg ha^{-1}) and resulted in higher above ground biomass (13.0 vs. 8.0 Mg). The more extensive rooting system in the sod based rotation was also more effective in taking up nitrates and ammonium, potentially reducing N leaching to ground water. Knowledge of N uptake used in conjunction with information on available soil N can be used to come up with N fertilizer recommendations for the new cropping systems.

Introduction

The importance of crop rotation as a way to improve soil conditions, reduce pests, increase yield and improve farm sustainability is well documented. However what is not always known is the exact role of the different components of rotations including crop development and interactions with the environment especially in new cropping systems. There is a lot of interest in developing a sod based peanut/cotton cropping in place of the traditional peanut cotton rotation for the SE. This is evident in the recent sod based conference held in Quincy, FL. in 2003, where over 30 articles were presented on many aspects of the sod based cropping systems. Reeves (1997) pointed out that the biggest benefits of including perennial grasses under conservation tillage in the traditional peanut/cotton rotation are to be derived from soil health. Although still in early stages, the Tri-States (Alabama, Florida, Georgia) results so far have shown this to be true. Preliminary results have shown improved soil water infiltration, reduced nitrate and ammonium leaching to ground water, and higher earthworm population densities (Katsvairo et al. 2004; Wright et al. 2004). An important component in the success of diverse rotation is the differential root development between the crop rotations. The roots for the different crops in rotations should explore different soil profiles and hence mine nutrients and moisture from different soil layers.

Plants with a more aggressive root growth patterns can be utilized to alleviate adverse soil conditions and make the soil more conducive for crops with a lesser aggressive growth habit. A compaction layer starting at 15-20 cm depth and continuing to 30 cm severely restricts root growth for most of the farmland in the southeast (Kashirad et al., 1967; Campbell et al., 1974). This has an impact on root morphology and consequently affects the amount of soil nutrients and moisture the roots can pick. The shallow rooted crops become susceptible to even the smallest amount of moisture stress under the sandy conditions typical of the southeast. Elkins et al. (1977) reported that perennial grasses such as bahiagrass and Bermuda grass can develop a deep root system which penetrates through the compaction layer. When the roots die, they decay and leave root channels which impact many positive attributes to soils structure and health (Elkins et al., 1977; Wright et al., 2004). A study by Long and Elkins (1983) reported a seven fold increase in pore sizes greater than 1.0 mm in the dense soil layer below the plow depth for cotton following 3 years of continuous bahiagrass sod compared to continuous cotton. The authors concluded that the dense soil layer had been penetrated by the bahiagrass roots and that, after the decay of the roots, pores were left that were large enough for the cotton roots to grow through. Deep rooted crops can pick soil moisture from deeper soil profiles and reduce the need for irrigation. Elkins et al. (1977) calculations showed that a plant with a rooting depth of 15 cm could experience water stress after only 3 days without rainfall. However, if the rooting depth was 152 cm, the plant would not experience water stress for a month after rainfall. Cropping systems which reduce the need for irrigation are essential and will alleviate the pressure on the current hotly debated Tri States (Alabama, Florida and Georgia) water talks.

Zobel (1992) reported that while the potential maximum root growth of plants is governed by genetics, there is response to the environment, including soil conditions. It is this small plasticity which we exploit in designing and management of diverse cropping systems. Thus, information on root development is essential for the designing and implementation of new diverse cropping systems (Merril et al., 2002).

Information on N management in sod based cotton production systems is important because N not only affects yield and quality (Fritschi et al. 2004) but excess N can end up in ground water. Most soils in the SE tend to be sandy and this exacerbates N leaching. Very little literature, if any, reports on N dynamics, availability and uptake in the bahiagrass/peanut/cotton rotation. Knowledge of N uptake in cotton coupled with an assessment of available soil N can be used to come up with fertilization rates for the new cropping system. Wright et al. (2004) reported mixed results for cotton yield in sod based vs. the conventional peanut/cotton rotation in Florida. They attributed the lack of clear differences between the rotations to confounding effects of N in the new system. N uptake is closely tied to root proliferation, with the larger and extensive rooting system likely to result in greater N uptake. At the same time root develop can be a function of rotation used.

Our objectives were to quantify and compare root biomass, crown diameter, length and area for sod based cotton production systems compared with the traditional peanut/cotton rotation. Because we also hypothesized that the resultant bigger root system in the sod based rotation would be more efficient at utilizing soil N, we tested this hypothesis by determining N concentration and total N uptake for cotton in the two cropping systems.

Materials and Methods

We initiated two rotation studies in Quincy, FL in 2000 to determine if introducing bahiagrass, a perennial grass to the conventional peanut/cotton rotation could change the rooting patterns of the subsequent cotton crop. The rotations for the first study were cotton-peanut-cotton-cotton (C-P-C-C), the commonly used rotation, and bahiagrass-bahiagrass-peanut-cotton (B-B-P-C). The rotations for the second study are:

Bahiagrass-Cotton-Cotton-Cotton-Cotton (B-C-C-C-C)
Bahiagrass-Bahiagrass-Cotton-Cotton-Cotton (B-B-C-C-C)
Bahiagrass-Bahiagrass-Bahiagrass-Cotton-Cotton (B-B-B-C-C)
Bahiagrass-Bahiagrass-Bahiagrass-Bahiagrass-Cotton (B-B-B-B-C)

Cotton roots were harvest at physiological maturity. The roots were carefully dug from a known area using shovels and spades. The roots were thoroughly washed to remove all soil and dirt. We measured the diameter at the root crown using calipers. The roots were scanned using an ordinary office paper scanner. The scanned images were imported into Assess, a digital image software. After calibration with a real size object the soft ware was used to determine root area, root length and root diameters.

We determined the N uptake at plant maturity in cotton by collecting whole plants and dried them at 60°C in a forced-air oven to constant moisture to determine biomass. The samples were then ground in a Wiley Mill, and plant N concentrations were determined by Kjeldahl procedures. Total N uptake was estimated as the product of biomass x whole plant N concentration.

Results and Discussion

Root Studies

Cotton in the bahiagrass rotation had larger root diameter, total root area and root length compared to cotton in the convectional rotation in 2003 (Table 1).

When bahiagrass roots die, they leave channels in the soil. The roots for the cotton in the bahiagrass could have grown through the channels and reach deeper depths than conventional cotton. In 2004, cotton in the B-B-B-B-C rotation had largest crown root diameter compared to the other rotations (Table 2)

The longer the plots were under sod the greater the crown root diameter. There were no statistical differences in either root area or length between the rotations in 2004. The year 2004 was much drier than 2003. It appears that in a drier year cotton in the sod rotation develops a tap root system as opposed to a more fibrous root system. Figs 1 and 2 show comparisons of the cotton root systems in the two years. In 2004 the tap root grew into the compacted zone. This was very evident when we were digging the roots. It should be pointed out that it was very difficult to dig up roots and complete recovery is next to impossible (Merril et al., 2004). This situation is exacerbated if the fine parts of the roots lie in the compacted soil layers. In our case the finer ends of the tap root was not recovered and neither were the adventitious roots which may have grew off the end of the tap root and as result embedded in the compaction layer.

Total N Uptake

Cotton in the sod rotation had a larger biomass in comparison to cotton in the conventional systems (peanut/cotton rotation) (Table 3). While there were no differences in N concentration between the rotations, the cotton in the sod rotation had the higher total N uptake. The improved soil conditions in the sod rotation enabled better root development which in turn sustained plants with a larger biomass and higher N uptake. In a companion article, Wright et al. (2004) showed that the larger rooting system also resulted in greater leaf area index.

Table 1. Cotton root diameter, area, and length at maturity at Quincy, FL. in 2003

Rotation	Diameter	Area	Length
	--cm--	--cm^{-2}--	--cm--
Cotton-Peanut-Cotton-Cotton (C-P-C-C)	1.63 a	57.4 a	460 a
Bahia-Bahia-Peanut-Cotton (B-B-P-C)	2.26 b	87.2 b	640 b

Table 2. Cotton root diameter, area, and length at maturity at Quincy, FL. in 2003.

Rotation	Diameter	Area	Length
	--cm--	--cm-^{2}--	--cm--
Bahia-Bahia-Bahia-Bahia-Cotton (B-B-B-B-C)	1.51 a	45.46 a	440 a
Bahia-Bahia-Bahia-Cotton-Cotton (B-B-B-C-C)	1.19 b	44.48 a	474 a
Bahia-Bahia-Cotton-Cotton-Cotton (B-B-C-C-C)	1.10 bc	42.98 a	465 a
Bahia-Cotton-Cotton-Cotton-Cotton (B-C-C-C-C)	1.03 c	41.15 a	431 a

Table 3. Cotton dry weight, N concentration and N uptake at physiological maturity for conventional and sod rotated cotton at Quincy, FL. in 2003.

Rotation	----biomass (Mg ha^{-1})-----
Bahiagrass-Bahiagrass-Peanut-Cotton	13.0
Cotton-Peanut-Cotton-Cotton	8.4
LSD (0.05)	2.3
	`---------conc (%)----------
Bahiagrass-Bahiagrass-Peanut-Cotton	1.76
Cotton-Peanut-Cotton-Cotton	1.73
LSD (0.05)	NS
	----N Uptake (Kg ha^{-1})-----
Bahiagrass-Bahiagrass-Peanut-Cotton	226
Cotton-Peanut-Cotton-Cotton	144
LSD (0.05)	41

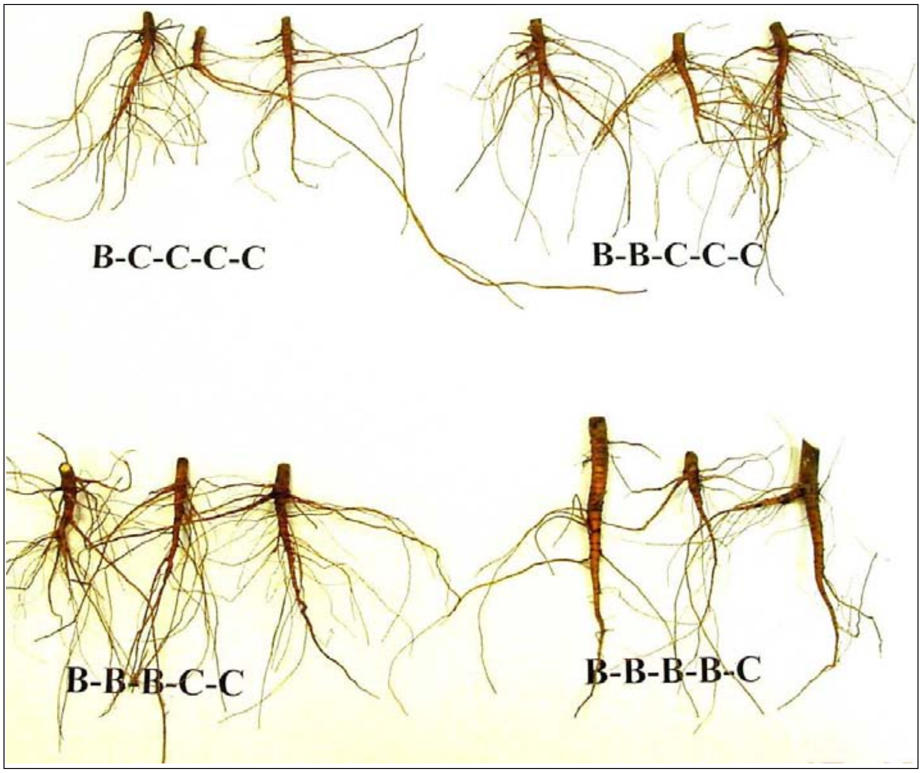

Fig 1.Comparison of root systems for four rotations in Quincy, FL. in 2004
Key: B-C-C-C-C = Bahia-Cotton-Cotton-Cotton-Cotton, B-B-C-C-C = Bahia-Cotton-Cotton-Cotton-Cotton, B-B-B-C-C = Bahia-Bahia-Bahia-Cotton-Cotton, B-B-B-B-C = Bahia-Bahia-Bahia-Bahia-Cotton

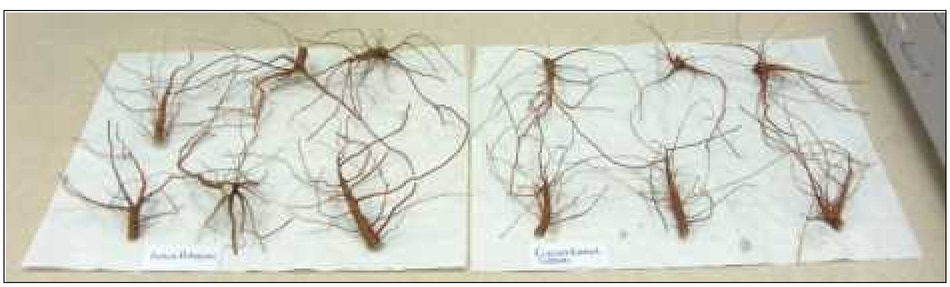

Fig 2. Comparison of two rotations in Quincy, FL. In 2004.
Key: B-B-P-C = Bahia-Bahia-Peanut-Cotton, C-P-C-C = Cotton-Peanut-Cotton-Cotton

Conclusion

Inserting bahiagrass in the rotations improved soil conditions and enabled the proliferation of cotton roots. Cotton in sod rotation had bigger root crown, root area and total root length compared to cotton in the traditional peanut cotton rotation in 2003 the wet year. In a drier year cotton in the sod rotation developed a tap root system. With extended bahiagrass rotations, the root crown diameter was larger the longer the land was under bahiagrass. Cotton in the sod rotation also had larger above ground biomass and total N uptake. A related study showed that the more extensive rooting system in the sod based rotation was also more effective in taking up nitrates and ammonium, potentially reducing N leaching to ground water (Katsvairo et al. 2004). Inserting bahiagrass in the traditional peanut/cotton rotation is an inexpensive way to improve soil health and ensuring plant health. Knowledge of N uptake used in conjunction with information on available soil N can be used to come up with N fertilizer recommendations for the new cropping systems.

Acknowledgement

Special thanks goes to Cynthia Davis Holloway, Iwona Jarczkowska for all the help with scanning the roots

References

Campbell, R. B., D. C. Reicosky, and C. W. Doty. 1974. Physical properties and tillage of Paleudults in the Southeastern Coastal Plains. J. Soil Water Conservation. 29:220-224.

Elkins, C. B., R.L. Haaland, and C.S. Hoveland. 1977. Grass roots as a tool for penetrating soil hardpans and increasing crop yields. Pages 21-26. Proceedings 34th Southern Pasture and Forage Crop Improvement Conference, Auburn University, Auburn, Alabama.

Kashirad, A. J., G.A. Fiskell, V.W. Carlisle, and C.E. Hutton. 1967. Tillage pan characterization of selected Coastal Plain soils. Soil Sci. Soc. Am. Proc. 31:534-541.

Katsvairo, T.W., D.L Wright, J.J. Marois and P Wiatrak. 2004. Soil Water Nitrogen in Sod Based Peanut/Cotton Cropping Systems. ASA Abstracts.

Merrill, S.D, D.L. Tanaka, J.D. Hanson. 2002. Root length growth of eight crop species in haplustoll soils. Soil. Sci. Soc. Am. J. 66:913-923.

Reeves, D. W., M. G. Patterson, and B. E. Gamble. 1997. Cover crops for weed control in no-till cotton. Proc. Beltwide Cotton Conf., January 6-10, 1997. New Orleans, LA. Vol. 1, pp. 628-629.

Wright, D.L., T.W. Katsvairo, J.J. Marois and P. Wiatrak. 2004 Crop yields in sod based peanut/cotton cropping systems in the deep south. ASA Abstracts.

Wright, D.L., J.J. Marois, T.W. Katsvairo, J. Rich and P. Wiatrak. 2004. Sod-based rotations for cotton/peanut in the southeast. Proc. Beltwide Cotton Conf. New Orleans, LA. 4-7 Jan. 2004. Published in this edition.

Zobel, R.W. 1992. Soil environmental constraints to root growth. Adv. Soil. Sci. 19: 27-51.