TITLE: The impacts of cotton and peanut rotations on the properties of a sandy soil: organic matter, aggregate stability, microbial biomass C, and enzyme activities.

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OBJECTIVES: This study investigated the impacts of cotton (*Gossypium hirsutum L.*) and peanut (*Arachis hypogaea L.*) rotations on the organic matter, aggregate stability, microbial biomass C, and enzyme activities of the Brownfield fine sand soil (Loamy, mixed, superactive, thermic Arenic Aridic Paleustalfs) at the Western Peanut Growers Research Farm (WPGRF). Studies are being conducted on the impacts of these rotations on mycorrhiza in soils.

SUMMARY OF THE RESULTS: The number of soil microorganisms and different enzyme activities, that participate in nutrient cycling and other processes, were not different after two years of a cotton and peanut rotation (PtCt) in comparison to continuous cotton (CtCt), and were only increased under continuous peanut (legume)(PtPt). Studies with other soils and crops rotations have shown there are increases in the soil enzyme activities and microbial numbers in comparison to monoculture. This is because doing crop rotations tend to add different type and amounts of residues to the soil as well as more nutrients. Thus, because of the high sand content of the Brownfield soil and due to the use of cropping systems based on peanut and cotton, two and three years with a continuous legume (peanut) was the only system capable of increasing soil microbial numbers and enzyme activities. It is well known, however, this is not a sustainable management system in terms of soil and plant health. One option could be to use alternative crops for rotations besides cotton because cotton-peanut rotations are not providing benefits to the soil, which is also an important factor that affects the peanut production. More samplings will be also needed to continue monitoring the trends in the soil properties studied.

METHODS AND PROCEDURES: Soil surface samples (0-12.5 cm=5 in) were taken in March and June 2002 from the span 7 under rotations of peanut (=Pt) and cotton (=Ct) such as CtCt and PtCt under 50%, 75%, and 100% evapotranspiration (ET) replacement irrigation levels, and from PtPt in the span 1 of pie 1 and 6 (also named span K) under 75% ET. Samples were taken again in September 2002 when the rotations became PtPtPt, CtCtP, and PtCtCt. Sampling will continue in 2003, so effects can be monitored over time. The Brownfield soil contains in average 91% sand, 7% clay, and 2 % silt. Three samples were taken per treatment and two field replicates were sampled. Each sample is a mixture of the top and the two low levels of a row by using a 5 cm (2 in) diameter probe core sampler (see diagram). After sampling, the samples were kept at 4^{o}C (39^{o}F) until soil microbiological analysis was performed the same month of the sampling.

The soil samples were analyzed for pH, organic C, total N, and soil aggregate stability (Table 1). The soil microbial biomass C (C_{mic}) was determined on a 15-g field-moist sample (oven-dry equivalent) by the chloroform-fumigation-extraction method (CFEM) described by Vance et al. (1987). β-glucosidase, β-glucosaminidase, alkaline phosphatase, acid phosphatase, phosphodiesterase, and arylsulfatase activities were measured in the air-dried soil according to the procedures of Parham and Deng (2001) and Tabatabai (1994). Future analyses on these samples will include the assessment of mycorrhiza in soils, and the characterization of the soil microbial community structure according to the analysis of the microbial fatty acid methyl ester (FAME) profiles.

Data analyses, including ANOVA and separation of the treatments means by their least significant differences, were performed using the general linear model procedure of the SAS system (1999).

RESULTS AND DISCUSSION: Soil organic C, aggregate stability, soil pH, enzyme activities (EA) and microbial biomass C (C_{mic}) were generally not affected by irrigation, and thus, an average is given for the CtCtPt and PtCtCt rotations including the three irrigation treatments. The soil C_{mic} was not affected by the irrigation levels in the CtCtPt and PtCtCt rotations, and the same could be expected if PtPtPt would be under different irrigation levels. Thus, our findings could indicate that an increase in peanut pathogens with increasing irrigation levels in continuous peanut is not necessarily related to increases in the number of soil microorganisms. However, the assessment performed does not provide information on the fluctuations of different microbial groups, and it is possible that the microbial population size remains the same but its composition (i.e., fungi vs. bacteria) could have changed. Thus, an assessment of the microbial community structure as affected by management will be performed.

The soil pH, total N content, and soil aggregate stability were not affected by the crop rotations studied (Table 1). These are generally soil properties that take several years to be impacted by management. The number of microorganisms in soils, however, can be impacted earlier than other soil properties. It is important to investigate the changes in soil microbial numbers because they control soil processes that impact plant productivity. These processes are the decomposition of the soil organic matter and plant residues, nutrient cycling, synthesis of humic substances, soil aggregation, degradation of pesticides, and N_2 fixation. This study found that the number of soil microorganisms (C_{mic}) was significantly higher under PtPt than in CtCt in March, and significantly higher under PtPt than in PtCt in June. In September, there were not significant differences in C_{mic} among the rotations, but the C_{mic} was increased in comparison to June (samples were taken under bare soil) due to the impact of plant and root growth (rhizosphere effect) on the soil microorganisms (Fig 1).

Microorganisms produce enzymes that participate in all the processes described (i.e., organic matter decomposition). Thus, monitoring the enzyme activities selected provides some indications on how carbon, nitrogen, sulfur, and phosphorus transformation have been affected in soils due to management. This study found that the 6 enzyme activities studied (β-glucosidase, β-glucosaminidase, acid phosphatase, alkaline phosphatase, phosphodiesterase, and arylsulfatase activities) were only increased in continuous peanut than in the other rotations (Fig 2). Because β-glucosidase is an enzyme that participates in the final step of cellulose degradation, the increase in this enzyme activity under continuous peanut indicates that more carbon (C) is incorporated in the soil by the peanut growth and its residues compared to the other systems. The increase in β-glucosaminidase activity under continuous peanut is important because this enzyme participates in processes whereby chitin is converted to amino sugars, which is one of the major sources of N in soil (Stevenson, 1994). The increase in the phosphatases and arylsulfatase activities in continuous peanut are important because the phosphatases (alkaline phosphatase, acid phosphatase, and phosphodiesterase) controls phosphorus availability in soils while arylsulfatase participates in the transformation of organic sulfur in soils. These findings, however, do not agree with previous studies for soils with less sand content, where soil properties are generally impacted by the crop rotations.

Thus, the results are indications that the enzyme activities studied are increased in this sandy soil only under a continuous legume (peanut) system. In addition, even though continuous peanut had higher soil enzyme activities, this was also the only system showing a decrease in these 6 soil enzyme activities from March to June 2002. This could not be related to seasonal changes, but more on the potential of enzyme stabilization by the soil, which is expected to be very low in sandy soils. Thus, the increases observed in the enzyme activities under continuous peanut could not be sustained over time. The enzyme activities were not increased from June to September due to plant and root growth, in contrast to the increase in the number of microorganisms. In summary, even though the number of microorganisms and enzyme activities were higher in continuous peanut, it is known that this is not a sustainable system, and thus, it may be needed to look for alternative crop rotations for peanut besides the peanut-cotton rotation in order to impact soil properties.

References

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Table 1. Selected chemical and physical properties in soils under cotton and peanut rotations

System[a]	Irrig. level	pH[b] March	pH[b] June	pH[b] Sept.	Organic C[c] March	Organic C[c] June	Organic C[c] Sept.	Total N[c] March	Total N[c] June	Total N[c] Sept.	Aggregate Stability[d] March	Aggregate Stability[d] June	Aggregate Stability[d] Sept.
	%				——— g kg^{-1} ———						——— % ———		
PtPt or PtPtPt	75	8.3	8.2	8.0	1.69	1.71	1.79	0.20	0.20	0.22	4.86	3.05	2.59
PtCt or PtCtCt													
	50	8.6	8.6	8.4	1.34	1.49	1.61	0.18	0.18	0.23	4.24	3.63	4.46
	75	8.6	8.8	8.4	1.40	1.43	1.63	0.18	0.18	0.20	4.37	3.00	3.88
	100	8.7	8.7	8.7	1.44	1.32	1.75	0.18	0.16	0.23	3.92	2.74	4.69
Avg[e]		8.6	8.7	8.5	1.39	1.53	1.67	0.18	0.17	0.22	4.18	3.10	4.34
CtCt or CtCtPt													
	50	8.4	8.2	8.5	1.55	1.66	1.38	0.18	0.20	0.24	6.35	4.54	4.59
	75	8.4	8.1	8.6	1.46	1.52	1.37	0.18	0.24	0.20	5.29	4.28	4.98
	100	8.4	8.0	8.5	1.22	1.54	1.43	0.15	0.20	0.24	4.70	4.21	4.06
Avg		8.4	8.1	8.5	1.41	1.57	1.40	0.17	0.21	0.23	5.11	4.34	4.54

[a] Peanut = Pt; Cotton = Ct. Two year rotation for March and June sampling. Three year rotation for September sampling.

[b] The pH was determined in a soil:water ratio of 1:2.5.

[c] Organic C and total N contents were determined in the Vario Max-ELEMENTAR CN analyzer (D-63452 Hanau; Germany).

[d] Aggregate stability was determined on the <2 mm soil samples according to the method by Kemper and Rosenau (1986).
Calculation: [stable soil aggregates/ (unstable soil aggregates + stable soil aggregates)]x100

[e] Average of the soil property for the three irrigation treatments within the rotation.

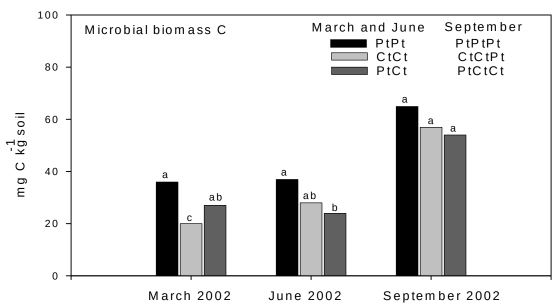

Figure 1. The impacts of cotton and peanut rotations on the soil microbial biomass.

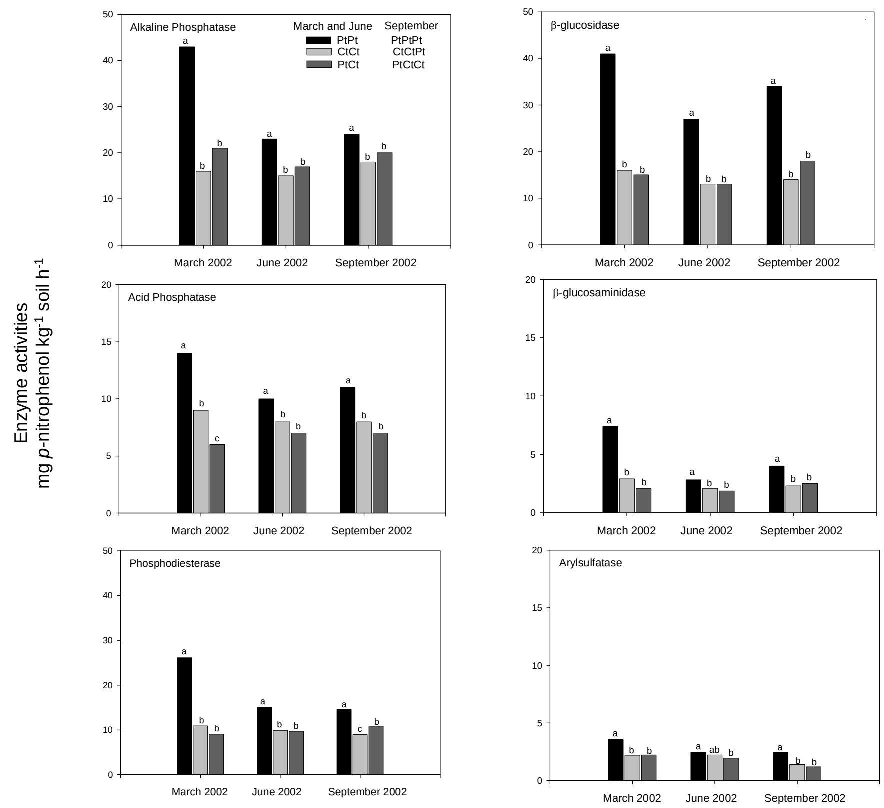

Figure 2. The impacts of cotton and peanut rotations on soil enzyme activities.