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Soil Enzyme Activities and Organic Matter Composition Affected by 26 Years of Continuous Cropping

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ABSTRACT

The study was to determine the long-term effects of subtropical monoculture and rotational cropping systems and fertilization on soil enzyme activities and soil C, N, and P levels. Cropping systems included continuous sorghum (*Sorghum bicolor* L.), cotton (*Gossypium hirsutum* L.), corn (*Zea mays* L.), and cotton/sorghum rotations after 26 years of treatment imposition. Soil under continuous sorghum and continuous corn had 15% and 11%, respectively, greater C concentrations than soil under continuous cotton. Organic C was 10% higher at 0–7.5 cm than at 7.5–15 cm. Total N followed similar trends with soil depth as organic C. Continuous sorghum had 19% higher total N than other crop species and rotations. With fertilization, continuous cotton had the highest total P at 0–7.5 cm and sorghum had the highest at 7.5–15 cm. Soil total P was 14% higher at 0–7.5 than at 7.5–15 cm, and fertilization increased 15% total P compared to unfertilized soil. Arylsulfatase, alkaline phosphatase, and β-d-glucosidase activity were the highest for sorghum and the lowest for cotton. Rotation increased enzyme activities compared to continuous cotton but not for continuous sorghum. Of all crop species and rotations, continuous cotton generally showed the lowest levels of organic matter and enzyme activities after 26 years. Fertilization significantly increased the yields for all cropping systems, but rotation had no significant effect on either sorghum or cotton lint yield compared to each crop grown in monoculture. Long-term cropping did not increase soil organic matter levels beyond short-term gains, indicating the difficulty in promoting C sequestration in subtropical soils.

Key Words: C sequestration, fertilization, monoculture, rotation, subtropical soil

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Soil C sequestration in agricultural soils is a valuable ecosystem service that reduces atmospheric CO_2 levels, but also has ancillary benefits including increased soil organic matter and fertility. These latter effects are beneficial for crop production through increases in the nutrient-supplying capacity of soils. Numerous studies have measured C sequestration potential for different crop species, rotations, and tillage regimes, but most have focused on temperate regions (Paustian *et al.*, 1997; Wright *et al.*, 2007; Dimassi *et al.*, 2014). The capacity of soils to sequester C is dependent on soil temperature as it affects microbial activity and thus rate of organic matter decomposition (Potter *et al.*, 1998). Increases in soil organic matter levels in subtropical soils are difficult to obtain because decomposition of crop residues often equals or exceeds organic inputs (Feller and Beare, 1997; Wright *et al.*, 2005). A few studies have measured the effects of cropping systems in subtropical soils of the USA, but most have focused on the assessment of reduced and conventional tillage (Wright *et al.*, 2005; Zibilske and Materon, 2005). Assessment of the effects of cropping systems should allow for determination of the role of crop species or rotation in organic matter cycling and enzyme activity in subtropical ecosystems (Zibilske and Bradford, 2007; Liu *et al.*, 2014).

Most impacts of cropping systems are observed in the surface soils where crop residues are deposited, or within the zone of tillage depth where crop residues are physically destructed and returned to soil (Paustian *et al.*, 1997; Wright *et al.*, 2008). Residue management and crop species influence organic matter stratification in the soil profile and microbial community dynamics in addition to C sequestration (Follett and Peterson, 1988; Salinas-Garcia *et al.*, 1997). Stratification of microbial activity and organic matter often

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develop in soils depending on tillage or crop species (Wright *et al.*, 2007; Peregrina *et al.*, 2014). Crop species can affect C and N distribution in soils through allocation of root exudates or residues, which is determined by rooting depth and root distribution in soils (Gale and Cambardella, 2000; Zibilske and Materon, 2005). Crop species that have deep rooting systems potentially increase soil organic matter levels more than shallow-rooted crops. Likewise, the quality of aboveground leaves and shoots or belowground roots also influences its persistence, as the residues of high quality (low C:N) are often decomposed faster than those of low quality (Ghidey and Alberts, 1993; Franzluebbers *et al.*, 1995; Soon and Arshad, 2002). In fact, degradation of fresh crop residues is often governed by C/N ratios (Chesire and Chapman, 1996; McDaniel *et al.*, 2014). Crops grown in rotation with other species may also tend to enhance organic matter levels due to inputs of varied quantity and quality. The greatest increase in soil organic matter is usually observed in intensive cropping systems where multiple crops are grown (Franzluebbers *et al.*, 1995; Dou *et al.*, 2014).

Changes in microbial community dynamics occur from the interactions of tillage, soil moisture, temperature, aeration, and substrate availability (Feng *et al.*, 2003). Different crop species or rotations have the potential to increase microbial activity and improve soil fertility (Wright *et al.*, 2005; Zhang *et al.*, 2014), which can ultimately increase the nutrient supply to crops through changes in the mineralization and immobilization of nutrients by microbial biomass (Salinas-Garcia *et al.*, 1997). Microbial activity responds quickly to soil management, such as fertilization, and is often used as an indicator of soil quality (Powlson *et al.*, 1987; Sparling, 1997). Excellent indicators of microbial activity are extracellular enzymes, which catalyze the hydrolysis of esters resulting in release of nutrients. They reflect nutrient cycling in soils and can be specifically linked to individual elements and can indicate the potential for nutrient generation from organic matter and thus the nutrient-supplying capability of soils.

Several studies illustrate the cumulative effects of cropping systems on soil microbial activity and organic matter accumulation after many years of treatment imposition (Franzluebbers *et al.*, 1995; Wright *et al.*, 2008), but little information is available for subtropical soils. Due to higher temperatures which support higher rates of soil microbial activity (Feller and Beare, 1997; Creamer *et al.*, 2015), subtropical soils may react differently from temperate soils in response to cropping system. The objective of this study was therefore to determine the long-term impacts of crop species and rotation on soil C, N, P, and extracellular enzyme activities for subtropical soils under variable fertility.

MATERIALS AND METHODS

Experiment description

A 26-year experiment was initiated in south Texas, USA in 1979 on a Victoria clay loam (fine, smectitic, hyperthermic sodic Haplusterts) with pH = 8.0. The climate is classified as subhumid subtropical and annual precipitation and temperature average 765 mm and 22 °C, respectively. The experimental design was a split plot within a randomized complete block. Cropping sequence was the main plot and fertilization was the split plot. The cropping sequences included continuous sorghum, continuous cotton, and continuous corn grown every year. Sorghum/cotton rotations were included in which each crop in the rotation was grown every year. Field plots measured 3.86 m by 15.2 m with row spacing of 0.96 m, and were replicated five times. The plots were shredded and disked after harvest and stubble was root plowed. Bedding and fertilizing were performed prior to planting. The experiment was conducted under reduced tillage with a maximum tillage depth of 15 cm and a total of five tillage operations annually. Fertilizers were banded preplant, with all three crop species receiving 44 kg N ha^{-1} and 22 kg P ha^{-1}. Each fertilized plot was compared with an unfertilized control in a split-plot design. Sorghum and corn were planted in late February or early March and harvested in July, while cotton was planted in March and harvested in August. Fields were fallow after crop harvest.

Soil sampling and analysis

Soil cores (10 cm diameter) were collected from the plots prior to planting. The samples from each plot consisted of two composited soil cores sectioned into 0–7.5 and 7.5–15 cm depths. Soil was air-dried and ground to pass a 5-mm sieve, and visible roots were removed before analysis. For measurement of soil organic C, total N, and total P, the soil was further ground to pass a 0.5-mm sieve. Soil organic C was measured by using the modified Mebius method (Nelson and Sommers, 1982). Approximately 0.5 g soil was digested with 5 mL of 0.5 mol L^{-1} $K_2Cr_2O_7$ and 10 mL of concentrated H_2SO_4 at 150 °C for 30 min, followed by titration of digests with $FeSO_4$. Soil total N was quantified by Kjeldahl digestion (Gallaher *et al.*, 1976) with NH_4^+-N analyzed colorimetrically. Total P was measured by the indophenol blue method (Kuo, 1996) after Kjeldahl digestion (Bremner, 1996).