CARBON AND NUTRIENT DYNAMICS IN REGENERATIVE COTTON PRODUTION SYSTEMS OF THE TEXAS SOUTHERN HIGH PLAINS

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ABSTRACT

Carbon (C) sequestration in soil provides environmental and agronomic benefits. However, building soil C in semi-arid cotton systems is difficult due to low rainfall, low biomass production and high temperatures. Regenerative systems, which utilize practices such as cover cropping and crop rotation, can increase the amount of C input in cotton (Gossypium hirsutum) production systems, but they may increase C losses via carbon dioxide (CO_2) due to increased respiration from soil microorganisms and plants. Thus, the C losses from increased CO_2 production must be discounted from added C when considering C sequestration potential. Nitrogen (N) dynamics can also be affected by regenerative practices. Increased heterotrophic activity in the soil can increase the occurrence of gaseous N losses as N_2O, via nitrification. Heterotrophic respiration may also lead to denitrification, as over stimulation of respiration can quickly deplete soil oxygen, causing anoxic conditions and the production of gaseous forms of nitrogen. This study evaluates the effects of the inclusion of a rye cover crop (Secale cereale), or rotation with wheat (Triticum aestivum), on cotton production in the Texas Southern High Plains. The inclusion of the rye cover crop did increase CO_2 loss compared to conventional practices, while emission from the cotton-wheat rotation were not different from conventional. Terminated rye biomass contains more labile c and has a lower C:N ratio, causing a stimulation of microbial activity and faster decomposition. Wheat stubble has a high C:N ratio and more recalcitrant C, so it is less likely to stimulate microbial activity. Our preliminary results indicate that cover crops can increase CO_2 production compared to conventional cotton production, while crop rotation with wheat does not, but further analysis of C inputs and soil C in both systems is required to gain a clear understanding of their sequestration potential.

INTRODUCTION

Carbon sequestration in semi-arid agroecosystems can be difficult given low net primary production. Adding to this challenge in the semi-arid Texas Southern High Plains is that cotton, a low biomass crop, is the most commonly produced crop, and conservation practices are utilized on less than half of all production acres. Regenerative agriculture is thought to benefit C sequestration by increasing the presence of living plants, thereby increasing C inputs. However, it is not clear how regenerative practices affect soil CO_2 emissions in semi-arid cotton cropping systems. Monitoring the effects of new production practices on CO_2 emissions is important because adding C to soil can increase C loss due to priming, negating some C sequestration benefits Agnew et al.,2010). Here, we assess the impact of two regenerative practices, cover crops and crop rotation, on soil CO_2 emissions from cotton cropping systems. These systems were compared to the regional standard practice of continuous cotton with conventional tillage. The overall goal of this study was to determine the impact of regenerative practices on C sequestration; however this paper specifically addresses soil C losses.

MATERIALS AND METHODS

This study took place at the Texas A&M AgriLife Agricultural Complex for Advanced Research and Extension Systems, located in Lamesa, TX. Management systems included continuous cotton with conventional tillage and winter fallow (CC), no-till cotton with cereal rye cover crop (CR), and a cotton-wheat-fallow rotation (CWF). The rotation was replicated twice so that at least one replication was in the cotton phase each year (CFW-C) and the other was wheat/fallow (CFW-F). Each system was irrigated at two different levels; base (60% ET replacement) and low (<30% ET replacement). Cotton varieties DP 2143 and FM 2498 were planted on May 15, 2023 at 53,000 seeds/acre. Soil CO_2 flux rates were determined via the chamber method using a Gasmet FTIR gas analyzer and an eight minute measurement time for each collar. Each system contained eight PVC collars installed in the soil (four in each irrigation level) from which measurements occurred approximately monthly from June to December 2023.

RESULTS AND DISCUSSION

Carbon Dioxide Emissions

Emissions in all systems at both irrigation levels peaked in July, corresponding to increased cotton growth and microbial activity (Figure 1). Wheat harvest in the CWF-F rotation occurred in late June, so peak emissions in July were likely due to peak wheat residue decomposition. After wheat harvest, the CWF-F system consistently had the lowest CO_2 emission rate under both irrigation levels (Figure 1). CR was the system that consistently had the greatest CO_2 flux rate, with rates significantly greater than at least one other system at every sampling event under base irrigation (Figure 1a). When comparing regenerative systems in the cotton phase, CR had significantly greater CO_2 flux rates than CWF-C at three of six sampling events (6/7, 8/23 and 12/20) at base (Figure 1a) and one of six (6/7) events at the low irrigation rate (Figure 1b). CWF-C flux rate was never significantly greater than CR during any event. Cumulative emissions in the CC, CR, CWF-C and CWF-F systems were 2,837, 3,659, 2,880 and 2,298 lbs CO_2-C per acre, respectively under base irrigation while at the low irrigation level they were 2,649, 2,938, 2,545 and 2,217 lbs CO_2-C per acre. At both irrigation levels the CR system was significantly different from CC while CWF-C was not due to the nature of the additional C input in those systems. Terminated rye biomass in CR was from immature plants, had a low relative C:N, and greater labile C compared to wheat stubble from the CWF system. As a result, rye biomass was decomposed quicker and converted to CO_2 while the wheat stubble was slower to decompose, preventing CO_2 emissions from the CWF-C system from exceeding those of CC. Similar results were observed by McDonald et al. (2019), where wheat cover and no tillage increased soil

CO_2 emissions relative to conventionally tilled cotton with winter fallow, while no-till cotton without cover did not. It is likely that the labile C source of wheat cover, similar to rye cover in this study, stimulated microbial activity causing increases in CO_2 flux compared to the other systems. Further data is needed to determine the full nature of C dynamics of regenerative systems investigated in our study, but we can conclude that the inclusion of rye cover in cotton systems increases C losses compared to rotation with wheat and conventional cotton production.

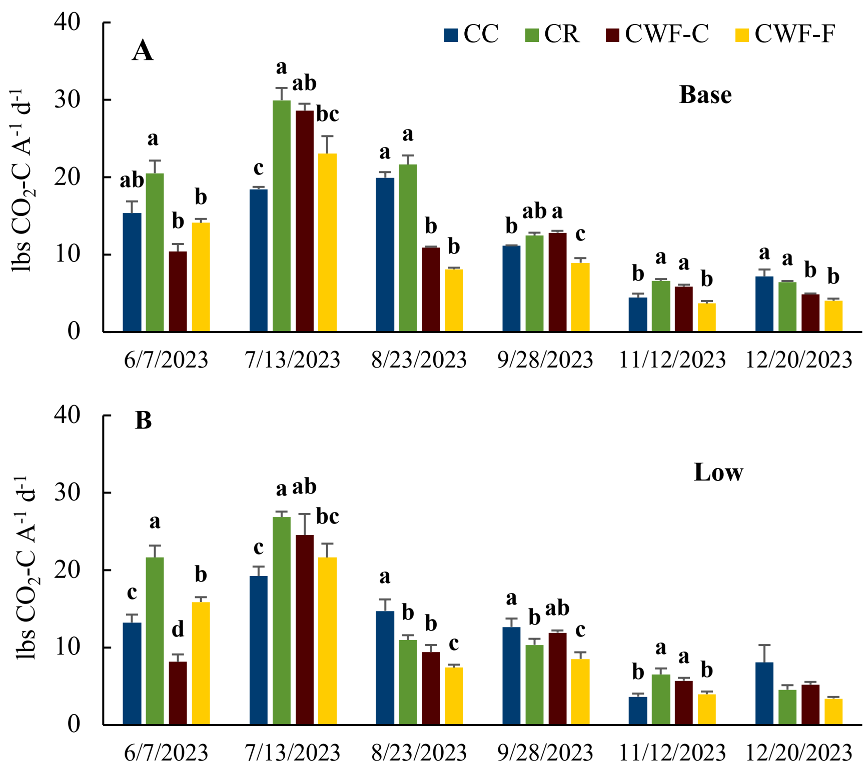

Figure 1. CO_2-C flux rates from June 7 to December 20, 2023 at base (a) and low (b) irrigation levels. Bars with the same letters within irrigation level and sampling event are not significantly different ($p<0.1$). Error bars are standard errors.

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