AGRIBLOSSOM
ISSN-2582-8258
A monthly peer reviewed e-magazine for Agriculture & allied Sciences

Sugarcane is champion crop for carbon sequestration

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Introduction

Carbon management may be a serious concern confronting the world nowadays. Several summits have been organized on this subject ranging from the Stockholm to Kyoto protocol. The current level of carbon within the atmosphere is 375 ppm. It is calculable that if the carbon increases in the atmosphere at the present rate and no positive efforts are pursued, the level of carbon in the atmosphere would go up to 800–1000 ppm by the end of the century, which can create havoc for all living creatures on earth. Soil is an important sink for carbon storage in the form of soil organic carbon. This form of carbon is also a matter of serious concern for sugarcane scientists because various researches reveal that the soil underneath intensive cultivation results in declining potential productivity due to deterioration in soil organic carbon, thereby proving a hurdle for sustainable agriculture. Sugarcane plants are the main source of the soil organic carbon, either from the decomposition of aerial plant parts or underground plant parts, e.g., root in the form of root death, root exudates and root respiration. About 40% of the photosynthates synthesized within the plant parts are lost through the root system into the rhizosphere within an hour and the rate of loss is influenced by many factors, e.g., plant age, several biotic and abiotic stresses etc. The rhizospheric surrounding of the plant is totally different compared to bulk soil with respect to physical, chemical & biological properties. Thus, the aim of this chapter is to provide an insight on the contribution of sugarcane plant roots for transfer of carbon from atmosphere to rhizosphere and further their significance in sustainable agriculture.

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Since the start of the industrial revolution, carbon dioxide concentration in the atmosphere has been rising alarmingly. Before the industrial revolution carbon concentration was around 270 ppm, however, these days it's around 372 ppm (Sage, 1995). If the pace of increase in carbon concentration remains constant and efforts are not made to reduce it, carbon concentration within the atmosphere would go up to 800–1000 ppm by the turn of the current century (Whipps, 1996). Carbon sequestration is a process of taking carbon dioxide from the atmosphere through crops and storing the carbon in the soil in the form of soil organic matter. An endeavor has been made in this chapter to understand how roots play a significant role in carbon transfer from the atmosphere into the soil.

Scientist has recently discovered that a process that occurs naturally in plants, especially sugarcane, plays an important role in countering CO_2 emissions and global warming. This is termed plantstone carbon and is also referred to as phytolith occluded carbon. The plantstone carbon has been extracting 300 million tonnes of CO_2 per year from the atmosphere and storing it securely in soil for thousands of years.

Plantstones carbon

Plantstones form as microscopic grains of silica in plant leaves, particularly grass crops such as sugarcane and wheat. During the plant growth period, a small proportion of organic carbon becomes encapsulated within the microscopic silica grains. Regardless of whether the plants die, burn, or are harvested, the carbon entrapped in the plantstone is highly resistant to decomposition. Therefore, unlike most plant matter, which readily decomposes and returns CO_2 to the atmosphere, the carbon in plantstone effectively removes CO_2 from the atmosphere. This process suggests that crop choice decisions by farmers could be a major contributing factor in the reduction of CO_2 from the atmosphere. The research of Parr and Sullivan's in crop plantstone yields has shown that different plant types produce varying amounts of plantstone carbon. Few crops have been identified as producing 1,000 times more plantstone carbon than other crop types. Moreover, varieties within a single crop type, such as sugarcane, have been found to produce widely differing quantities of plantstone carbon. Thus, the farmer's decision of choice of crop type and/or cultivar has a considerable impact on the amount of CO_2 extracted from the atmosphere and securely stored in the soil of their farms. Some of the plantstone research shows that sugarcane is a champion crop for carbon sequestration. It sequestrates up to 0.66 tonnes of CO_2 per ha per year in plantstones while many other crops (especially legumes) sequestrate comparatively little or no CO_2 by this process. Thus, the benefit that farmers growing sugarcane is not just limited benefits such as the sugar they produce, but also the environmental services they provide by locking up increased amounts of carbon in the plantstones that are produced abundantly by the crop. Increasing carbon sequestration by plantstones is by no means limited by a need to change the types of crops that farmer grows. For a sugarcane farmer, the decision to choose to grow one sugarcane variety instead of another can result in an extra 0.25 tonnes of CO_2 per ha per year being sequestered in the soil inside plantstones. The research shows that there are no crop yield penalties involved in choosing to grow high plantstone carbon yielding cultivars over low plantstone carbon yielding cultivars.

There should be provided by the governments, for an incentive to farmers to grow high plant stone yielding crops and crop varieties. Carbon trading systems result in farmers having the potential to earn additional income without detracting from existing income. Plantstone carbon is a powerful tool to counter CO_2 emissions providing land managers the opportunity to play an even greater role in the fight against global warming. The discovery of phytolith is interesting and timely. Farmers should participate in emerging carbon markets; it is necessary to demonstrate that carbon can be sequestered in the soil in a way that is permanent and measurable. The plantstone turned into an income source. It can be recognized in future carbon trading schemes.

Sugarcane Plant Carbon Storage

The carbon stock in different plant parts of sugarcane, including roots, shoots, and leaves differ significantly. The highest amount of carbon stock was observed in leaves followed by roots while the carbon stock in shoots demonstrates the lowest value. Leaves showed around 11% - 24% more carbons stored in the leaves compared to the roots and shoots. The total carbon storage in sugarcane biomass including aboveground parts (shoots and leaves) and belowground part (roots) in different cultivation systems like planted cane and ratoon of different years vary significantly. The highest root carbon stock is observed in planted cane and ratoon of first-year and further, the root carbon contents in next coming year ratoon gradually diminish. The stored carbon in shoots of ratoon first (R-I) occurs highest compared to that of shoots of ratoon second (R-II) and ratoon third (R-III) and in other cultivation systems. The carbon stored in leaves of the R-I cultivation system and in planted cane cultivation system indicates the highest and the lowest values observed in other ratoon cultivation systems.

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Sugarcane cultivation practices for carbon sequestration

The carbon content of most soils is now about one-third less than that in its native condition. Fortunately, the sugarcane cultivation has stopped this net loss to the atmosphere. This has come through higher levels of biomass production by sugarcane crop, the return of greater proportions of crop residue, use of a by-product of these crops, and less tillage of succeeding ratoon and no-till. Simultaneously, better fertility management through soil testing and proper nutrient application also leads to the lowering of greenhouse gas emissions. Irrigation water traps some CO_2 because irrigated soil produces high crop residues which sequester carbon at a rate of 0.16 to 0.27 Pg per year. The enhanced soil organic matter levels sequester CO_2, which enhances sustainability and reduces soil erosion.

Sugarcane roots and rhizospheric carbon

The compounds released by plant roots that deposit in the rhizosphere are many and complex, often ranging from mucilage, root border cells, extracellular enzymes, simple & complex sugars, phenolics, amino acids, vitamins, organic acids, nitrogenous macromolecules as purine and nucleosides to inorganic or gaseous molecules such as HCO_3^-, OH^-. Transfer of carbon from the atmosphere to the soil through the plant system is dependent on a gradient which is maintained continuously as a result of constant removal of exudates carbon from the soil solutions either by biotic (soil microbial uptake) or abiotic process, like sorption. Soil provides technical barriers in measuring the flux of individual carbon compounds, but in a study on maize, it was found that 0.5–10% of fixed carbon is transferred into the soil.

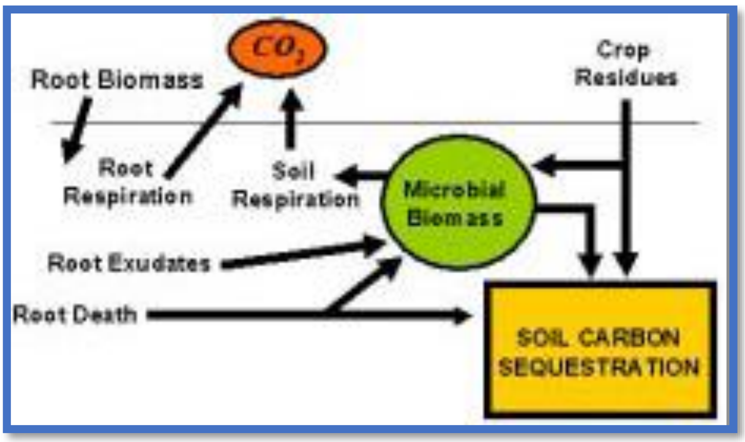

Figure 1. Soil carbon sequestration through plant roots

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Conclusion

The sugarcane ratoon has the highest potential to sequester carbon than main crop. The sugarcane farming act as an important tool for carbon sequestration and consequently enhancing the mitigation of climate change impacts. Sugarcane root acts as a medium for transfer of atmospheric carbon into soil in the form of root exudate (phenolics, organic acids, amino acids and phyto-siderophores, vitamins, purines, enzymes, inorganic ions/gaseous molecules, root border cells and Sugars) in the rhizosphere. Root lysis and root exudates contribute significant quantity of carbon deposited in sub-surface. These deposits have the potential for contribution to long-term soil carbon sequestration due to slow oxidation in sub-surface soil. Carbon components affect production by reducing pH, nutrient mobilization and microbial growth. The exact amount of sequestration depends on soil-management practices, edaphic factors, climate and the amount and quality of plant and microbial inputs. The carbon transfer via roots generates a new idea that allows better decisions on the specific use of crop rotation, fertilization and soil amelioration. Carbon sequestration certainly contributed in reducing atmospheric CO_2 concentration and mitigates drought, salinity stress and desertification. It is most viable approach towards sustainable agriculture. Thus, sequestered soil carbon used for agriculture, forestry and potential option to mitigate global climate change.

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