

Sugarcane:

Boom crop for carbon sequestration

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Soils, especially specifically managed agricultural soils can be a large low-cost source of greenhouse gases (GHGs) with extra potential advantages to agricultural output. Most horticultural soil experts and agronomists feel that, most agricultural soils can store lot of carbon and even a slight increase in carbon stocks across large home-stead land regions may result in important GHGs reductions. Sugarcane is one of the crop that can cope with rising carbon dioxide (CO₂) levels due to its natural advantages. Some of the major natural endowments in relation to growing CO₂ concentrations in the atmosphere include a very low carbon dioxide compensation point and the unique property of sequestering carbon in the form of phytoliths or plant stone. The crop has been given two significant abilities namely, low compensation point (varying between 0–10 ppm) and carbon sequestering capacity (181 kg C sequestered/ha year), which assists in regulating the effect of rising CO₂ concentration on the crop.

Keywords: Carbon sequestration, Greenhouse gas, Plantstone carbon, Sugarcane

THE world today may be seriously concerned about carbon control. Several meetings have been planned on this topic, from Stockholm to the Kyoto protocol. There are 375 ppm of carbon atoms in the atmosphere at the moment. Calculation shows that if carbon emissions continue to rise at their current rate and proactive measures are not taken, the level of carbon in the atmosphere might reach 800–1000 ppm by the end of the century, which could be disastrous for all of the world's living things. In the form of soil organic carbon, soil serves as a significant sink for carbon storage. Scientists studying sugarcane are also very concerned about this type of carbon since studies show that intense farming causes the soil's potential productivity to decline because the soil's organic carbon is degrading. This puts sustainable farming at risk. Sugarcane (*Saccharum officinarum* L.) cultivation leaves behind around 20 tonnes/ha of biomass residue after harvest

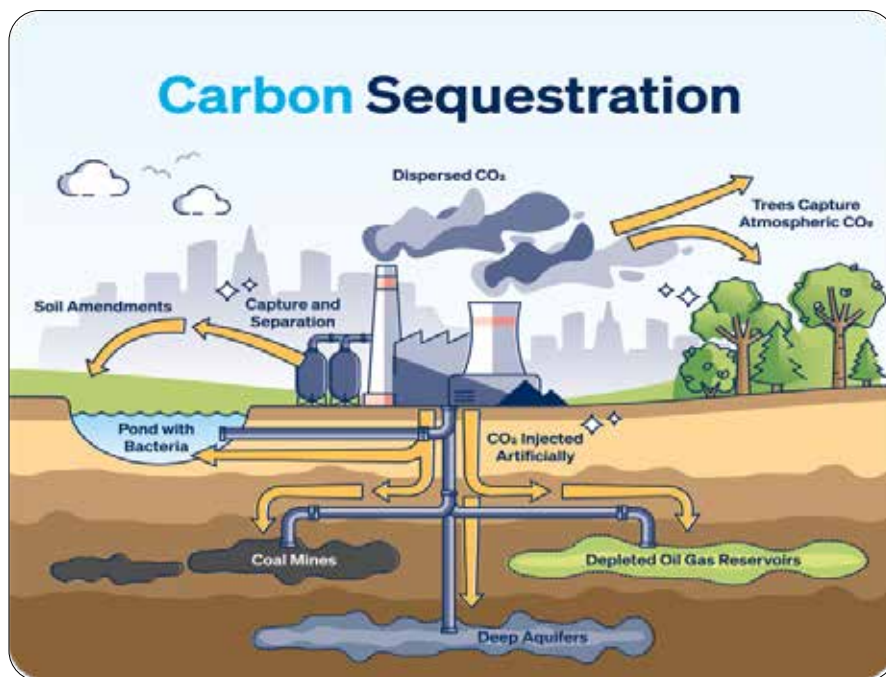
and processing. Sugarcane plants provide the most soil organic carbon, either through the decomposition of aerial plant parts or by the breakdown of underground plant parts such as, roots in the form of root respiration, root exudates and root death. Various factors including plant age, diverse biotic and abiotic difficulties, etc influence the rate of loss, with around 40% of the photosynthates generated inside plant parts being lost through the root system into the rhizosphere. Regarding physical, chemical and biological characteristics, the plant's rhizospheric environment differs greatly from bulk soil. The article sheds light on the role played by sugarcane plant roots in the transfer of carbon from the atmosphere to the rhizosphere.

Before the industrial revolution, carbon concentrations were around 270 ppm and today, they are at 420 ppm. Using various crops, CO₂ is eliminated from the atmosphere, the carbon is then captured and

stored in the soil as soil organic matter. Scientists have learned that a natural mechanism in plants, mainly in sugarcane is crucial in reducing CO₂ emissions and the effects of global warming. This is referred to as plant stone carbon or phytolith occluded carbon. Plant stone carbon has securely stored 300 million tonnes of CO₂/year for thousands of years, which would otherwise be lost to the atmosphere.

Plant stone carbon

Plant leaves, especially those of grassy plants like wheat and sugarcane, contains minute silica grains that coalesce to form plant stones. While the plant grows, a small amount of organic carbon becomes trapped among the minute silica grains. The carbon in the plant stone is exceedingly resistant to deterioration, whether the plants die, burn, or are harvested. In contrast to ordinary plant matter, which rapidly decompose and release CO₂ into the atmosphere, the carbon in



Carbon sequestration cycle
Source: VectorMine/Shutterstock.com

and leaves have drastically different carbon stocks. The maximum carbon stock was found in the leaves, followed by the root, while the lowest carbon stock was found in shoot. The CO_2 released by the sugarcane crop in the field during processing amounted for 20.65 million tonnes, although the crop absorbed 228.89 million tonnes of CO_2 from the Indian atmosphere during its life cycle. The carbon accumulated in the leaves was 11%, and 24% higher than in the roots and shoots. With different farming techniques, such as planted cane and ratoon of different years, the total carbon stored in sugarcane biomass, comprising above ground portions (shoots and leaves) and below-ground components (roots) varies considerably. The planted cane and ratoon of the first year have the maximum root carbon stock, and the root carbon content in the ratoon of the following year steadily decreases. Ratoon first (R-I) shoot has the largest concentration of carbon stored as compared to ratoon second (R-II) and ratoon third (R-III) shoots and other cultivation systems. The R-I and the planted cane cultivation systems have the highest and lowest level of carbon storage in their leaves, respectively, compared to other ratoon farming systems.

Carbon sequestration practices in sugarcane

Most soils today contain around one-third less carbon than they did in their original state. Thankfully,

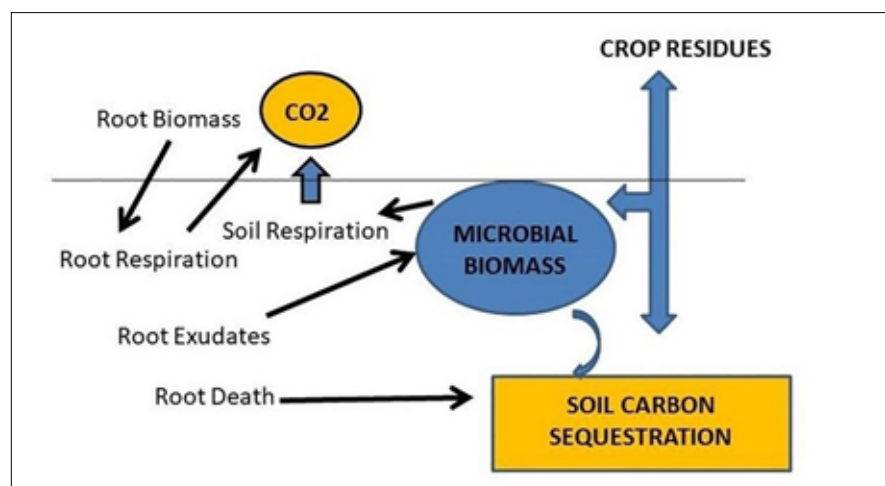
plant stone successfully removes CO_2 from the environment. This procedure raises the possibility that farmer decision on crop selection could play a significant role in removing CO_2 from the atmosphere.

Additionally, it has been discovered that different cultivars of the same crop type, i.e. sugarcane, produce wildly different amounts of plant stone carbon. As a result, the amount of CO_2 collected from the atmosphere and securely maintained in the farmer's farm heavily depends on their crop type/cultivar selection. According to certain plant stone studies, sugarcane is the best crop for carbon sequestration. Unlike many other crops (especially legumes), its plant stones can store up to 0.66 tonnes of CO_2 /ha/year. By increasing the quantity of carbon locked up in the abundantly generated plant stones, sugarcane producers are able to give environmental services in addition to restricted benefits such as the sugar that they produce. Making a choice for one sugarcane variety over another can result in an additional 0.25 tonnes of CO_2 being stored per hectare per year in the soil within plant stones for a sugarcane farmer. According to the investigation, growing high plant stone carbon yield cultivars over low

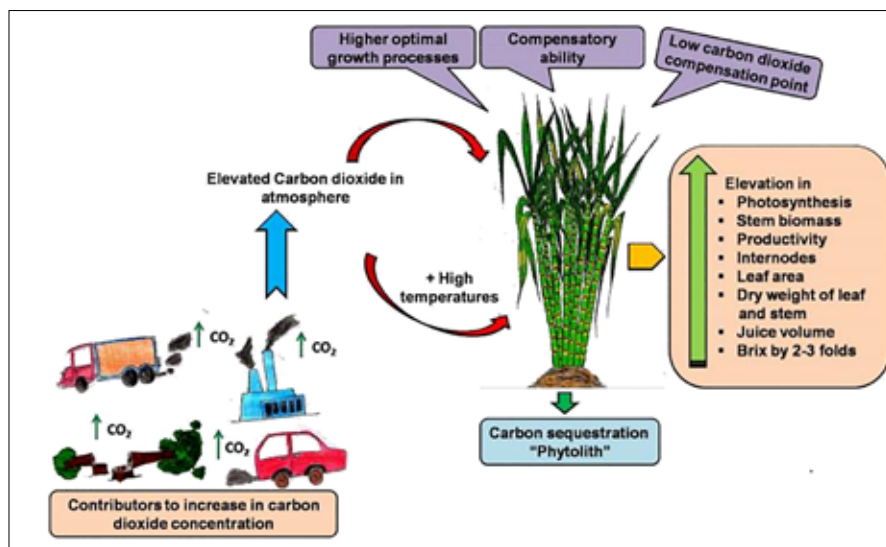
plant stone carbon yield cultivars, has no negative consequences on crop output. The government should offer farmers with incentives to cultivate crop varieties and high plant stone generating crops. A potent technique to reduce CO_2 emission through plant stone carbon gives land managers a chance to contribute even more in the fight against global warming. Farmers should participate in developing carbon markets, as its imperative that carbon be permanently and measurably trapped in the soil.

Carbon storage in cane

Various sugarcane plant components such as roots, shoots



Soil carbon sequestration through plant roots



Impact of increased CO₂ concentrations on sugarcane crop (Misra *et al.* 2019)

the production of sugarcane has halted this net loss to the atmosphere. In order to achieve this, sugarcane crops have increased their biomass production, returned more significant amounts of crop waste, used a by-product of these crops, and require less tillage from future ratoon and no-till crops. Better fertility management achieved through soil testing and appropriate nutrient application has simultaneously reduced greenhouse gas emissions. Due to the high

agricultural residues produced by irrigated soil, which absorb carbon at a rate of 0.16–0.27 Pg/year, irrigation water captures some CO₂. Increased levels of soil organic matter capture CO₂, improving the sustainability and reducing soil erosion. Because sugarcane fields are grown in many ratoons, where plants re-sprout after harvest and are only tilled and replanted every 4–6 years, minimal tillage is already widely employed. On the other hand, post-harvest residue burning should be avoided

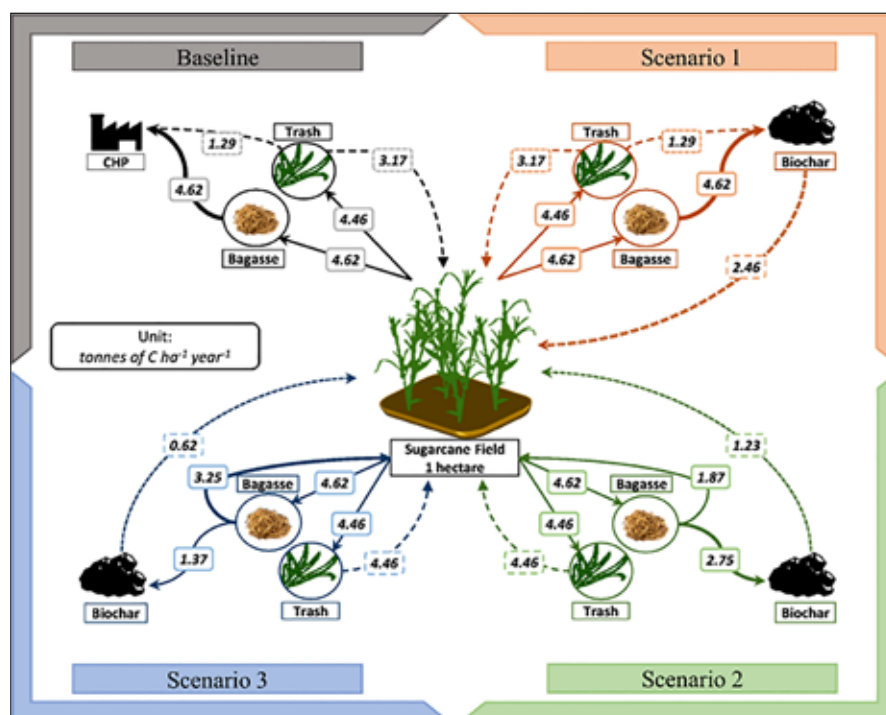
because it has been shown to reduce SOC (soil organic carbon) in different cropping systems. The use of a surface layer of mulch, which keeps the soil temperature consistent and minimizes SOC oxidation, is the second-way through which no-till management enhances SOC sequestration.

Role of sugarcane in managing elevated CO₂

Plant roots release a range of intricate compounds into the rhizosphere, including mucilage, root border cells, extracellular enzymes, simple and complex sugars, phenolics, amino acids, vitamins, organic acids, nitrogenous macro-molecules such as purine and nucleosides and inorganic or gaseous molecules such as HCO₃⁻ and OH⁻. Carbon can be conveyed from the atmosphere to the soil via the plant system by continuously removing exudate carbon from soil solutions via biotic (soil microbial absorption) or abiotic mechanisms such as sorption. Sugarcane, as a C₄ plant has an extremely low CO₂ compensation threshold, ranging from 0–10 ppm. This indicates that they can deplete all of the atmospheric CO₂ in a closed ambient atmosphere at a fixed temperature. This is not the case with other crops such as wheat, soybean etc which have a high CO₂ compensation point (40–100 ppm). Under high CO₂ levels, the stomata and leaf transpiration mechanism in sugarcane plants are partially closed due to a C₄ plant. This generates less sap flow, which increases the potential of xylem and as a result, improves the plant water status. This has resulted in an increase in sugarcane stalk fresh mass.

SUMMARY

The agricultural crop with the most significant potential to sequester carbon is sugarcane under ratoon crop. Sugarcane cultivation is an important tool for carbon capture, which aids in the process of mitigating the consequences of climate change. Sugarcane roots operate as a route



Scenario flowchart representing the fate of the bagasse and trash C produced/ha/year on a sugarcane field

Source: <https://www.nature.com/articles/s41598-020-76470-y>

for transferring atmospheric carbon into the soil through root exudate in the rhizosphere. Carbon deposits beneath the soil surface due to root lysis and root exudates. Due to slow oxidation in subsurface soil, these deposits may help with long-term soil carbon sequestration. Carbon components impact production by lowering pH, mobilizing nutrients and promoting microbial growth.

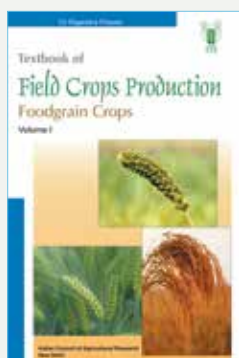
The volume of carbon sequestered is affected by climate, edaphic conditions, soil management approaches and the botanical and the microbiological input amount and quality. Using crop rotation, fertilizing and soil improvement is more effectively made possible by the carbon transfer via roots. Carbon sequestration undoubtedly helps in lowering the atmospheric

CO₂ concentration and lessen the effect of desertification, drought and salinity stress. It is the most practical strategy for sustainable agriculture. Soil carbon sequestered is employed in forestry, agriculture and act as a possible means of reducing global warming.

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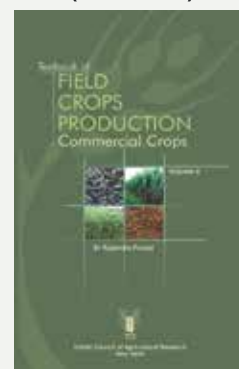
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