Research Journal of Chemical and Environmental Sciences
Res J. Chem. Environ. Sci. Vol 8 [3] June 2020: 01-06
Online ISSN 2321-1040
CODEN: RJCEA2 [USA]

Website: www.aelsindia.com/rjces.htm

RJCES

REVIEW ARTICLE

Chemical Properties and organic carbon fractions of soil influenced by use of organic manures and fertilizers: A review

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ABSTRACT
Soil organic carbon (SOC) pool is the largest among the terrestrial carbon (C) pool. The management and enhancement of SOC is important for sustainable agriculture. SOC is also the source and sink of atmospheric CO_2 and plays a key role in global C cycling. Soil labile C pools are not static but dynamic entities over time. Changes in salinity and sodicity affect soil physical and chemical properties, which subsequently alter nutrient cycles and decomposition processes. Soil chemical properties are altered, impacting upon nutrient cycling as well as SOC. Therefore, there is a clear linkage between management practices of soil fertility through their effect on salinity and sodicity and their potential to alter soil C stocks and fluxes.
Key words: Microbial biomass carbon, Dissolved organic carbon, manure, Fertilizer

Received 01.02.2020 Revised 04.03.2020 Accepted 12.04.2020

INTRODUCTION

The rate of C accumulation or loss is dependent on the balance between the amount of C input and C loss. Carbon input is dependent on plant inputs and biomass accumulation, as soil organic carbon (SOC) levels are dominated by deposition from litter fall and roots. Carbon inputs in salt-affected soils are also likely to decrease as vegetation growth declines due to the direct effects of toxic ions and increases in osmotic potential, and indirect effects in the form of declining soil structure.

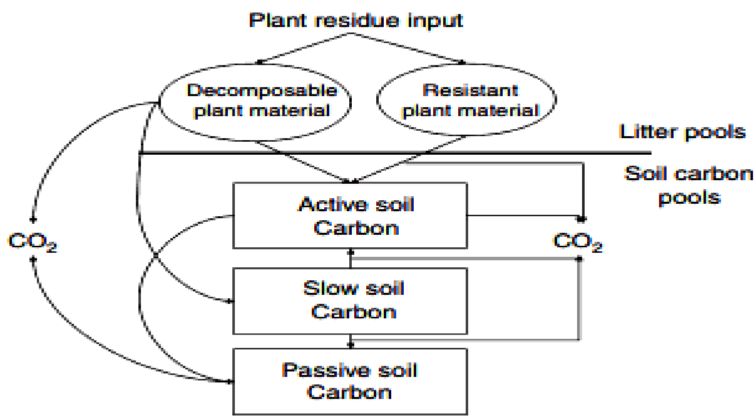


Diagram:1 Conceptual model of soil C pools and turnover [13, 14]

Total organic C in soil is comprised of several dynamic pools, broadly grouped as labile pool or active pool, slow pool and passive recalcitrant pool. The labile pools consist of soil microbial biomass C, water soluble C, water soluble carbohydrates etc [4]. These pools have been used as sensitive indicators for judging C dynamics in soil in short to medium term basis [19, 17]. The passive pools are comparatively more stable than labile pool and are slowly decomposable having a larger turnover period. The three main SOC pools are: (i) the active pool, with a turnover time in the order of weeks; (ii) the slow pool with a turnover time in the order of decades; and (iii) the passive pool with a turnover time in the order of millennia.

The active pool is made up of readily oxidisable materials including, the microbial biomass and its metabolites, and is largely controlled by climate and residue inputs, which provide a nutrient source for plants [26]. The slow and / or very slow pools contain moderately decomposable material within macro- and microaggregates and particulate organic carbon [21]. The passive or recalcitrant pool includes stable C formed from the turnover of microbial and slow SOC that are chemically resistant to, or protected from further microbial degradation [26]. A large proportion of this pool is charcoal, which is found in all Australian soils [8].

The SOC associated with sand-sized particles (53–2000 μm) comes from partly decomposed dead plant and animal materials that have a relatively low turnover time, which is between the turnover times of active and passive C pools. This fraction of SOC is more sensitive to land management when compared with total SOC and better suited to predict changes in soil quality. The SOC associated with silt and clay particles is relatively stable, due to physical protection, and provides a good measure of the physical protection capacity of the soil, which is positively related to the silt and clay content in the soil.

Organic-matter fractions obtained by physical fractionation, either occupying a more labile (light fraction, free and occluded) or a more humic compartment (heavy fraction), respond differently to changes in the environment. Physical fractionation methods are considered less destructive and more related to in situ SOM function and structure than chemical methods. In systems dominated by superficial litter deposition, such as forests and dense savannas, accumulation of LF is more intense than in systems in which underground litter deposition predominates (root litter), such as native and cultivated pastures [23]. Occluded LF comprises a diversified group of organic compounds of reduced size and more advanced state of decomposition than the free fraction [10].

Density fractionation is used to separate SOC into the light (LF) and heavy fractions (HF).The SOC in the LF, with a density of 1.6–2.0 $g\cdot cm^{-3}$ is not firmly associated with soil particles and consists mostly of free organic matter (FOM) and pieces of plant residues. The SOC in the LF has a high C:N ratio and a relatively low turnover time. The LF typically has between 20% and 30% SOC, which is formed by the decomposition of plant residues. The SOC in the HF with a density of >1.6–2.0 $g\cdot cm^{-3}$ exists as organo-mineral complexes and is associated with soil mineral particles. Compared to the LF, organic C in the HF is less sensitive to land management changes, but represents the soil's long-term C sequestration capacity.

Density fractionation, in contrast to chemical extractions, allows for isolation of fractions as intact as possible, and is theoretically related to the spatial arrangement and interactions of organic compounds and minerals. The method separates light and heavy fractions , taking advantage of the difference in density between minerals and organic material, and often by additional physical dispersion. Accordingly, in a solution of appropriate density, organic-dominated material, with little to no interactions with minerals, floats, while organic–mineral associations sink.

The microbial biomass carbon (MBC) is an important component of soil organic matter and comprises 1%–3% of total organic carbon [14, 20]. It has a rapid turnover rate and is also considered to be a reservoir of labile nutrients. Since it is not easy to identify small changes in different, stabilized pools of soil organic matter, microbial biomass and water-extractable pools of soil organic carbon are considered sensitive indices that characterize changes in biological conditions caused by soil management practices. Application of gypsum and organic amendments influences microbial biomass carbon in a sodic soil [3] and in soils irrigated with sodic water (SW). Kaur *et al.* [16] concluded that MBC is a more sensitive indicator than organic C to the changes in soil properties due to long-term irrigation with SW in presence and absence of amendments.

Chemical definition of DOC is an impossible task; it is operationally defined as all organic substances smaller than 0.45 μm. Studies showed that dissolved organic carbon (DOC) contents and soil attributes are sensitive to changes in total SOC. In the short to medium term, biological properties and the readily decomposable fraction of SOC, such as DOC, are much more sensitive to soil management than is SOM as a whole.DOC reflects the equilibrium between dissolved and solid phases, and is closely related to microbial activity, thereby being a sensitive indicator of total SOM and changes in soil management and, by extension, soil quality. Additionally, transport and bioavailability of metal and organic pollutants in contaminated areas are also affected by DOC dynamics [29].

Due to inadequate or unpredictable supplies of good-quality water in many arid and semi-arid regions of the world, farmers are left with no option but to use poor-quality sodic groundwater for irrigating crops. Long-term and indiscriminate use of sodic waters can cause salts to accumulate in the soil and Na that is present not only adversely affects the physical and chemical properties of the soil [14-19], but also influences the quality of soil organic carbon, its biotic components, and several decomposable and extractable C pools as well [24]. To offset the harmful effects of sodic water, application of gypsum is a common practice. In addition, organic manures like farmyard manure, green manure, and crop residues can also be used as amendments as they decompose and form carbonic acid which in turn can mobilize Ca from $CaCO_3$ and other Ca-bearing minerals in the soil [7], thereby minimizing sodic irrigation effects on crop yields [6, 7].

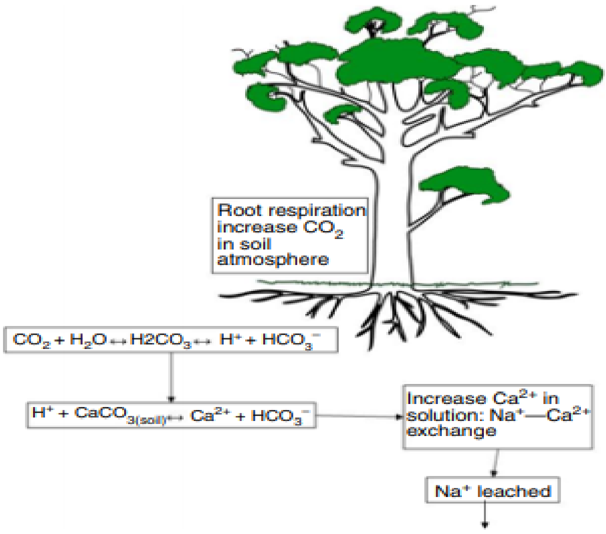


Diagram:2 Processes involved in the removal of Na by vegetation in sodic soils (source: 21, 22).

Carbon dioxide from plant root respiration dissolves in the soil solution, while increasing the partial pressure of CO_2 due to the microbial decomposition processes also causes a decrease in pH through the production of H_2CO_3. Concurrently, H^+ is also released from plant roots. These processes facilitate the dissolution of carbonate minerals, including $CaCO_3$, which increases the concentration of Ca^{2+} and displaces exchangeable Na^+ [18, 22, 23]. The overall aim of this review is to determine how soil C stocks and turnover rates are affected by many combination of FYM and fertilizers through increasing salinity and sodicity.

MATERIAL AND METHODS

Soil sampling and analysis

Collection and preparation of soil samples

soil samples from a system was collected by an auger, air dried, grounded and sieved (2mm)

Chemical analysis.

Dissolved Organic Carbons (DOC)

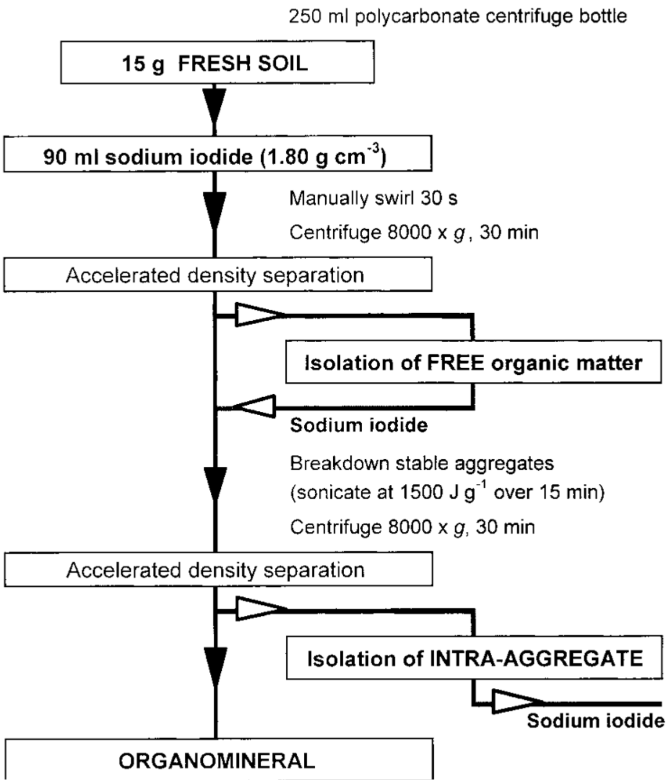
Fifty ml of deionised water was added into 10 g of soil and shaken, later subjected to centrifuge at 8000 rpm. The solution was filtered and dissolved organic carbon was determined by dichromate acid oxidation method .

Microbial Biomass Carbon (MBC)

Microbial biomass was determined by the Chloroform ($CHCl_3$) fumigation method proposed by Vance et al. Each moist soil sample was fumigated with ethanol free $CHCl_3$ for 24 hours. Following fumigant removal, the soil was extracted with 0.5 M K_2SO_4 (1: 4, soil: solution ratio) by shaking, followed by filtration and estimation of carbon by dichromate oxidation method. Biomass carbon is the difference between the extracted carbon in fumigated and non- fumigated soil.

Light and Heavy carbon Fractions

Light fraction of soil organic matter in soil samples was isolated by densimetric method modified by Janzen et al. The represented soil samples (10 g) of coarsely ground soil (<2mm) were dispersed with a NaI solution (40 ml) having specific gravity of 1.70 g cm^{-3} Suspensions were allowed to equilibrate for 48 hours and then light fraction are removed by vacuum. The unsuspended material represented heavy fraction (HF). The LF and HF was washed with successive aliquots each of $CaCl_2$ and distilled water, dried, ground and analyzed for total carbon by dichromate digestion of modified Walkley and Black`s rapid titration method as described by Nelson and Sommers.



RESULTS AND DISCUSSION

pH, EC

Long-term irrigation with sodic-water (SW) significantly increased the soil pH. The maximum pH (10.1) was recorded in the top layer in the unamended SW treatment. Application of gypsum up to 25% gypsum requirement significantly reduced soil pH in both soil layers. Further reduction in soil pH due to application of gypsum at 50% requirement was not significant. Among organic amendments, application of FYM and GM significantly reduced the mean soil pH.

Mean ECe increased from 0.90 dS/m under CW to 2.04 dS/m under SW irrigation. Further increase in mean ECe was observed upon application of gypsum at 25% (2.23 dS/m) or 50% (2.83 dS/m) requirement. The increase in ECe due to application of gypsum was observed in the unamended as well as in the organically amended treatments. This can be ascribed to release of salts into soil solution due to gypsum dissolution. Application of organic materials also increases the release of salts into soil solution as a result of mineral dissolution due to increase in partial pressure of carbon dioxide and organic acids [5]. Maximum ECe of 3.06 dS/m in the present investigation was observed in the unamended SW + 50% gypsum requirement treatment. It is well below the hazardous level (4.0 dS/m) of salinity in soil [1].

Organic carbon:

Decrease in organic C content due to irrigation with SW compared with CW was not significant in the unamended plots. Application of gypsum did not affect organic C content. Organic amendments significantly increased soil organic C content over unamended treatments. Application of FYM resulted in maximum increase in organic C (0.71%) followed by GM (0.51%). Organic C content in FYM-treated plots increased by 68% compared with the unamended treatment. The corresponding increases in GM- and WS treated plots were 21 and 19%, respectively. Organic sources such as FYM, GM, and crop residues decompose slowly, resulting in organic C accumulation in soil [25-27]. Among the organically amended treatments, FYM–SW recorded significantly higher organic C content than unamended SW treatment (68%) followed by GM (24%),and WS (20%) treatments, respectively. Application of gypsum at 50% requirement in the FYM treatments resulted in further increase in organic C content.

Microbial biomass carbon

Long-term SW irrigation significantly decreased MBC compared with CW irrigation in soil. MBC was not detected in the unamended and WS-treated plots receiving SW irrigation. Reports in the literature show MBC content ranging from 100 to 600 mg/kg soil in non-saline soils [27, 2] and 125 to 445 mg/kg soil in saline soils [23]. Decline in MBC content under long-term SW irrigation can be ascribed to a decrease in microbial populations and their activity due to higher ESP and pH, and deterioration in physical properties of soil [3]. Tripathi *et al*. [28] found that higher ECe (up to 16 dS/m in coastal saline soils) caused significant decrease in MBC and microbial activities. Addition of carbon to soil through FYM, GM, and WS stimulated microbial activity [21, 4], which increased the MBC content of soils. Application of carbon through WS resulted in significantly higher MBC than in the control but less than FYM and GM treatments, because the high C :N ratio of WS slows down the mineralisation process [2], particularly in a sodic environment. In the unamended treatment, application of gypsum at 25% requirement significantly increased MBC from 19.8 (SW) to 39.6 mg/kg soil. Further increase in gypsum dose to 50% requirement significantly increased MBC to 69.3 mg/kg soil in the surface 0–75 mm soil layer. In the 75–150 mm soil layer, application of gypsum at 12.5% and 50% requirement significantly increased MBC from traces (SW) to 19.8 and 39.6 mg/kg soil, respectively. Batra *et al.* [3] observed that higher microbial biomass in gypsum-treated sodic soil was in line with lower ESP and resultant better physical properties and higher availability of nutrients. The improvement in soil properties upon application of gypsum and organic amendments created a better soil environment for improved microbial activity [24] and resulted in increase in MBC.

LFC &HFC

Knowledge about the nature, distribution and turnover of organic matter in the soil is critical to understand its storage of carbon and nutrients. Light fraction act as a transitory pool of organic matter between fresh residue and humified soil organic matter. Light fraction carbon is considered to include decomposing plant material and animal residues that have rapid turnover rate and thus can be important source of plant nutrients.Much of this material is derived from plant residues, but the LFC also contains appreciable amount of microbial and micro faunal debris including fungal hyphae and spores.

Light fraction carbon is one of the several indicators that may be used to evaluate the quality of soil organic matter [11]. It permit the assessment of the effect of decomposition on soil fertility, residue persistence and organisms. The C:N ratio of light fraction is usually intermediate between that of the whole soil and the plant tissue [11].

Janzen *et al.* [12] stated that higher amount of LFC in manure applied treatments confirmed that light fraction which is mainly composed of partially decomposed plant residues, is highly labile and can change rapidly in response to management practices and accounted for 2-18%.

Banger *et al*. [2] suggested on the basis of 16-years of application of chemical fertilizers and FYM in a sandy loam soil that LFC content of soil increased and observed accumulation of 56% greater in organic treatment followed by 53 % greater in integrated and 30 % greater in NPK as compared to control treatment.

CONCLUSION

Long term effect of SW deteriorate the chemical and biological properties of Soil. Gypsum application help in maintaining favourable soil pH, exchangeable sodium percentage and organic matter content ,hence improve chemical properties of soil. Organic material such as FYM, pressmud & crop residue further improves the chemical and biological properties of soil .Sodic water can be used successfully for irrigation along with gypsum and organic manures

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CITE THIS ARTICLE

D Rathi, DevRaj and Sushil. Chemical Properties and organic carbon fractions of soil influenced by use of organic manures and fertilizers: A review. Res. J. Chem. Env. Sci. Vol 8 [3] June 2020. 01-06