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Role of soil organic matter in maintaining sustainability of cropping systems

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Abstract

Soil organic matter (SOM) has long been recognized as an important indicator of soil productivity. The SOM refers to the organic fraction of the soil exclusive of undecayed plant and animal residues. It plays a crucial role in maintaining sustainability of cropping systems by improving soil physical (texture, structure, bulk density, and water-holding capacity), chemical (nutrient availability, cation exchange capacity, reduced aluminium toxicity, and allelopathy) and biological (nitrogen mineralization bacteria, dinitrogen fixation, mycorrhizae fungi, and microbial biomass) properties (Fageria N. K. 2012). Green manure crops can increase cropping system sustainability by reducing soil erosion and ameliorating soil physical properties by increasing SOM and fertility levels, by increasing nutrient retention, by helping control weeds and by reducing global warming potential (Cavigelli and Thien, 2003). Application of organic manures in the tea growing soils boost up the soil organic carbon, humic and fulvic acid content in soil in one way, and significantly increase the soil microbial populations, microbial biomass and enzymatic activity (Rajkonwar *et al.*, 2016). Uptake of NPK by rice–rice sequence was higher when 75% recommended NPK dose was applied through chemical fertilizers to both winter and autumn rice along with 25% N through crop stubbles only in case of winter rice. Thus, integrated nutrient management involving organic and inorganic sources not only increases the availability and uptake of major nutrients but also helps in yield sustainability in rice–rice cropping system under long run in acid soils. (Baishya *et al*., 2015). Among the sources of available organic manures, vermicompost contains a higher percentage of nutrients necessary for plant growth in readily available forms. It increases macropore space resulting in improved air-water relationship in the soil, which favourably affects plant growth. The application of organic fertilizers including vermicompost favourably affects soil pH, microbial population and soil enzyme activities. Vermicompost treatment plots displayed better results with regard to growth and fruit yield of tomato plant as compared to control. (Mukta *et al.*, 2015).

Keywords: Organic matter, cation, vermicomposting, toxicity

Introduction

Organic matter refers to the solid, no mineral portions of the soil that originate from plant and animal residues (Aust and Lea 1991) [6]. According to the Soil Science Society of America (1997) [72], soil organic matter (SOM) can be defined as the organic fraction of the soil exclusive of undecayed plant and animal residues. Hayes and Swift (1983) [39] used the term to refer more specifically to the nonliving components, which are a heterogeneous mixture, composed largely of products resulting from microbial and chemical transformations of organic debris. This transformation, known as the humification process, gives rise to humus, a mixture of substances that has a degree of resistance to further microbial attack. Adequate organic matter in the soil plays an important role in improving sol physical, chemical, and biological properties and consequently improves or maintains sustainability of cropping systems. In agricultural systems, maintenance of soil organic matter has long been recognized as a strategy to reduce soil degradation (Mikha and Rice 2004) [54]. The major role organic matter plays in soil is to stabilize soil aggregates, making soil easier to cultivate, increasing soil water-holding and buffering capacities, and releasing plant nutrients upon mineralization (Carter and Stewart 1996) [18]. There is no critical level of organic matter established for different cropping systems below which soil quality decreases markedly or irreversibly, but decreasing SOM is still of concern because it might adversely affect some or all of these properties (Webb *et al*. 2003) [84]. Organic matter also adsorbs heavy metals, which may be toxic to plants or may contaminate soils and reduce its quality. Wander *et al*. (1996) [82] reported that SOM is potentially the single best integrator of inherent soil productivity and should be developed as index of soil quality. Maintenance of soil quality, which is the capacity of soils to sustain productivity, maintain environmental quality, and promote plant and animal health (Doran and Parkin 1994) [22], is the key to agricultural sustainability (Wander *et al*. 1996) [82]. Soil organic matter consists of a heterogeneous mixture of components with hydrophilic and hydrophobic functional groups (Jenkinson 1988; Ellerbrock *et al*. 2005) [43, 25]. The SOM formation is a consequence of a feedback relationship between organic carbon (C) input and decomposition (Hsieh 1996). Hence, the amount of organic matter in a soil that has been under a given system of cropping and management for a long time depends on how much organic matter enters the soil each year and how fast this organic matter decomposes in the soil (Jenkinson and Ayanaba 1977) [42]. Turnover of SOM represents energy (carbon; C) and nutrient flows of a soil and therefore is closely related to intrinsic soil productivity (Hsieh 1996). Improving SOM content is difficult in arable lands because of the rapid decomposition rate of added organic materials. In cultivated soils, fertility management practices may not change SOM contents by more than 10% during time periods of 0–10 years (Paustian, Parton, and Persson 1992; Wander and Traina 1996) [59, 82]. Small magnitude of C change may easily be overshadowed by natural soil C heterogeneity. This may be the reason that even though it is well recognized that SOM should be maintained to sustain soil productivity, SOM contents are generally not effectively used within sites to assay management practice impacts on soil productivity or fertility (Wander and Traina 1996) [82]. Although, by addition of organic materials, total SOM content may not improve, there may be beneficial changes in the microbial biomass and/or SOM characteristics (Doran *et al*. 1987; Liebhardt *et al*. 1989; Wander *et al*. 1994) [23, 47, 83].

Soil Organic-Matter Fractions

The SOM is a heterogeneous, dynamic substance that varies in C and nitrogen (N) content, molecular structure, decomposition rate, and turnover time (Oades 1988; McLauchlan and Hobbie 2004) [57, 53]. However, SOM can be conceptually defined as a series of fractions that comprise a continuum based on decomposition rate (Stanford and Smith 1972; Paul and Clark 1996) [73, 58]. The various fractions of SOM varied in degree of decomposition, recalcitrance, and turnover rate, and management practices may affect these fractions differently (Schimel, Coleman, and Horton 1985; Echeverria *et al*. 2004) [67, 24]. Tirol-Padre and Ladha (2004) [79] and McLauchlan and Hobbie (2004) [53], however, reported that SOM is mainly divided into two groups or fractions. These fractions are labile, which is smaller in size and most rapidly decomposable, and recalcitrant, which is the larger pool with slow turnover. Labile fractions of organic matter may decompose in a few weeks or months. The labile fraction of organic matter is composed of plant litter, macro organic matter or light fraction, the living component or biomass, and non humic substances that are not bound to soil minerals (Theng, Tate, and Sollins 1989; Tirol-Padre and Ladha 2004) [76, 79]. The most common components of rapidly decomposable organic-matter fractions are carbohydrates, amino acids, peptides, amino sugars, lipids, cellulose, hemicellulose, waxes, fats, resins, and lignin. Labile SOM fractions are highly responsive to changes in C inputs to the soil and will provide a measurable change before any such change in total organic matter (Gregorich and Janzen 1996; Tirol-Padre and Ladha 2004) [37, 79]. The stable fraction of organic matter may persist in the soil for years or even decades. Stable organic constituents in the soil include humic substances and other organic macromolecules that are highly resistant to microbial decomposition or that are physically protected by adsorption on mineral surfaces or entrapment within clay and mineral aggregates (Theng, Tate, and Sollins 1989; Tirol-Padre and Ladha 2004) [76, 79]. Stable fractions of organic matter are probably more appropriate and representative for C sequestration characterization; Tirol-Padre and Ladha 2004) [79]. The SOM can also be divided into functional pools based on turnover rates (Tirol-Padre and Ladha 2004) [79]. A small pool (1 to 5%) with rapid turnover that may take weeks to years, a large pool with a slow turnover that may take decades, and another large pool with very slow turnover that may take centuries (Scholes and Scholes 1995) [68].

Organic-Matter Content of the Soil

Soils having widely different organic-matter contents are often found even within the same climatic zone. Such differences in organic-matter content of soils are normally attributed to the effects of vegetation, microbial population, temperature, and moisture content and management practices adopted in crop production. Natural processes leading to the development of soils having variable organic-matter contents are related to the so-called factor of soil formation. OM = f (time, climate, vegetation, parent material and topography) where f stands for “depends” or “function of” and the dots indicate that other factors may be involved.

Organic Matter Versus Soil Physical Properties

Physical properties of soils are those characteristics, processes, or reactions of a soil that are caused by physical forces and can be described by, or expressed in, physical terms or equation (Soil Science Society of America 1997) [72]. Examples of physical properties are soil texture, structure or porosity, bulk density, and water-holding capacity. The soil physical properties mainly influence air–water relations in the soil, which, in turn, affect the growth of plants. Addition of organic matter to soil improves these physical properties. With the improvement of soil physical properties, there is improvement in soil quality and consequently improvements in crop productivity. Main soil physical properties that are influenced or having positive correlation with SOM are summarized in Table 2, and a detailed discussion is given in the following sections.

Texture

Soil texture is the relative proportions of the various soil separates in a soil. The three soil separates that makes soil texture are sand (2 to 0.02 mm in diameter), silt (0.02 to 0.002 mm), and clay (0.002 mm or less in diameter). Soil texture is unchanged by cultural and management practices. Organic-matter content of the soil is highly related to its clay content.

Table 1: Soil organic-matter function in the soil for the sustainability of cropping systems soil property

Soil property	Changes in soil property in favor of sustainability of cropping systems
Physical	Texture Structure Bulk Density Water-holding capacity
Chemical	Availability of macronutrients Availability of micronutrients Cation exchange capacity Aluminum toxicity Allelopathy Heavy metal toxicity
Biological	Nitrogen mineralization bacteria Dinitrogen fixing bacteria Mycorrhiza fungi Microbial biomass

Structure

The soil is a porous mixture of inorganic particles, organic matter, air, and water. This mixture also contains a large variety of living microorganisms. The inorganic particles and organic matter make up the soil solids, while the soil pore space is occupied by air and water. Soil structure is the combination or arrangement of primary soil particles into secondary units or peds. The secondary units are characterized on the basis of size, shape, and grade. Each ped is in turn made up of small clusters or aggregates of soil particles. Exceptions are sandy soils, which exhibit single-grain characteristics. Soil structure is an important property that mediates many physical and biological processes and controls SOM decomposition (van Veen and Kuikman 1990; Mikha and Rice 2004) [81, 54].

Bulk density

Bulk density of soil is defined as the mass of dry soil per unit bulk volume. The unit of soil bulk density is Mg m–3. Bulk density is a physical property of the soil that can be used as a simple index to the general structural condition of the soil. Although it cannot be interpreted in a specific manner as with degree of aggregation, aggregate stability, or pore size distribution, bulk density does provide a general index to air–water relations and impede root growth. The bulk density of most surface soils usually ranges from 1.0 to1.6 Mg m–3 (Fageria and Gheyi 1999) [26]. Soil organic matter significantly influences soil bulk density.

Water-holding capacity

Knowledge of water dynamics in soil is essential for a better management of irrigation, fertilization, and leaching of nutrients and heavy metals from the soil profile (Gerard, Tinsley, and Mayer 2004) [35]. One of the most important effects of organic-matter addition to the soil is that it changes the soil's water retention characteristics, which is generally related positively to crop production. A reduction in available water capacity is considered the foremost contributing factor in loss of soil productivity caused by erosion. This reduction in available water capacity is attributed to changes induced in the soil water-holding characteristics of the root zone or by reduction in the depth (thickness) of the rooting zone (Bauer and Black 1992) [12].

Organic matter versus soil chemical properties

Organic matter brings many significant changes in soil chemical properties such as reducing Al toxicity and decreasing allelopathy in crop plants. It improves availability of macro and Icronutrients to crop plants.

Availability of macronutrients

Organic matter is a major indigenous source of available N that it contains as much as 65% of the total soil P and provides significant amounts of sulfur (S) and other nutrients essential for plant growth (Bauer and Black 1994) [11]. Also universally accepted is that the C fraction is used by microorganisms as a major energy source for metabolic activity, in the process altering nutrient availability (Bauer and Black 1994) [11]. Organic matter has many of the characteristics of an ideal N fertilizer. Organic N is not readily leached or denitrified and its mineralization rate is dependent on many of the same factors that affect plant growth, such as temperature and water availability. The N-supplying power of both organic matter and legumes is particularly important in today's economy, as the cost of N fertilizer has increased dramatically in recent years.

Availability of micronutrients

Organic matter plays a key role in the soil micronutrient cycle. Knowledge of the nature of the organic ligands that form complexes with metal ions and of the properties of the complexes thus formed will lead to a better understanding of factors that affect trace element availability to plants (Stevenson 1991) [74]. Organic chemicals with two or more functional groups that can bind with metals to form a ring structure are known as chelating agents (Soil Science Society of America 1997) [72]. Organic-matter fractions such as fulvic acids can form chelate structures with some metals. These chelates can bind micronutrients such as Cu, Fe, zinc (Zn), and Mn and improve their availability to plants.

Cation exchange capacity

Organic matter, depending on its level in the soil, can make a significant contribution to the soil's CEC. Increasing organic-matter level in the soil increased soil CEC (Kapland and Estes 1985; Fageria and Gheyi 1999) [44, 26]. The marked effect of organic matter on soil CEC can be explained by the high CEC of organic matter. Kapland and Estes (1985) [44] reported that an incremental 1% increase in SOM on a dry-weight basis (starting near zero) resulted in a corresponding increase of 1.7 cmol CEC kg–1 of soil.

Aluminum Toxicity

Organic matter plays an important role in controlling the level of Al in the soil solution (Bloom, McBride, and Weaver 1979a, 1979b) [13]. When grown at the same pH, plants from soils high in organic matter do not exhibit the symptoms of Al toxicity common to plants grown in soils low in organic matter (Thomas 1975; Coleman and Thomas 1964) [77, 20]. Foy (1964) [34] suggested that the reason alfalfa could grow in a Bayboro soil with high Al was because the Al was chelated by organic matter, thus reducing the amount of Al in solution. Kapland and Estes (l985) [44] reported that the critical Al level of alfalfa was correlated with SOM levels (r = 0.88). An increase of 1% in SOM on a dry-weight basis (starting from about zero) increased critical Al level by 0.3 cmol kg^{-1}.

Allelopathy

Allelopathy is defined as any direct or indirect harmful or beneficial effect by one plant on another through the production of chemical compounds that escape into the environment (Rice 1974) [64]. The International Allelopathy Society defined allelopathy as any processinvolving secondary metabolites produced by plants, algae, bacteria, and fungi that influence the growth and development of agricultural and biological systems. This definition considers all biochemical interactions between living systems, including plants, algae, bacteria, and fungi, and their environment (Macias *et al*. 1988) [48]. Willis (1985) reported that the basic conditions necessary to demonstrate allelopathy in natural systems are the following:

1. A pattern of inhibition of one species or plant by another must be shown.
2. The putatively aggressive plant must produce a toxin.
3. There must be a mode of toxin release from the plant into the environment.
4. There must be toxin transport and/or accumulation in the environment.

5. The afflicted plant must have some means of toxin uptake.
6. The observed pattern of inhibition cannot be explained solely by physical factors or other biotic factors, especially competition and herbivory.

Organic matter versus soil biological properties

Soil organic-matter contents significantly influence soil biological properties such as N-mineralizing bacteria, dinitrogen-fixing bacteria, mycorrhizae fungi, and total microbial biomass. These properties are summarized in Table 2 and detailed discussion is given in the following sections.

Nitrogen-mineralizing bacteria

Nitrogen mineralization is the conversion of organic N to inorganic N by microbial activity. Urea and ammonium sulfate are dominant N carriers used for crop production around the world. The oxidation of the ammonium form of N fertilizers, which form nitrate (NO3 –), can be explained by the following equation:

$$NH_4^+ + 2O_2 \Leftrightarrow NO_3^- + H_2O + 2H^+$$

The oxidation of NH_4^+ in this equation is known as nitrification, and heterotrophic and autotrophic bacteria can carry it out. The most important autotrophic genera of bacteria are *Nitrosomonas* and *Nitrobacter*. Adequate quantity of organic matter in the soil reduces soil acidity and improves activities of these N-mineralizing bacteria. With the reduction of soil acidity, there is improvement in the nodule formation of clover by indigenous rhizobal strain (Almendras and Bottomley 1987; Howieson, Robinsons, and Ewing 1993) [4, 40].

Denitrification

Denitrification is the reduction of N oxides (usually nitrate and nitrite) to molecular N or N oxides with a lower oxidation state of N by bacterial activity (denitrification) or by chemical reactions involving nitrite (chemo denitrification) (Soil Science Society of America 1997) [72]. Denitrification is one of the major mechanisms for N loss from the soil. Hauck (1981) [38] reported that denitrification can cause losses of as much as 30% of the applied N under field conditions. The process of dentrification can be expressed in the form of following equation:

$$NO_3^- \text{ (nitrate)} \Rightarrow NO_2 \text{ (nitrite)} \Rightarrow NO \text{ (nitric oxide)} \Rightarrow N_2O \text{ (nitrous oxide)} \Rightarrow N2 \text{ (dinitrogen)}$$

Most denitrification is biologically catalyzed and closely linked to bacterial respiratory metabolism (Aulakh, Doran, and Mosier 1992) [5]. In chemo denitrification, generation of N gas is catalyzed by abiotic agents, but this process may only be of importance in acidic or frozen soils (Christianson and Cho 1983) [19].

Dinitrogen fixation

Dinitrogen fixation is the conversion of molecular nitrogen (N2) to ammonia and subsequently to organic N utilizable in biological processes (Soil Science Society of America 1997) [72]. Although mixed cropping and crop rotation with legumes was practiced for centuries, the basis of their benefit was not recognized until Boussingault (1838) [13], a French scientist, presented evidence that the legumes fixed N from the air (Burris 1998) [15].

Mycorrhizae Fungi

One of the most important groups of soil microorganisms is mycorrhizal fungi. Vesicular– arbuscular mycorrhizal (VAM) fungi are present in nearly all-natural soils, and these fungi infect the greater majority of plants including the major food crops (Fageria *et al*. 1997) [27]. Micorrhizae fungi have been shown to improve the nutrition of the host plants for nutrients that are diffusion limited, such as P, Zn, Cu, and Fe (Tinker 1982; Marschner and Dell 1994; Smith and Read 1997) [71]. Micorrhizae fungi receive carbohydrates from the host plant in return for the development of an extensive hyphal network that effectively provides the plant with a substantial increase in root surface area (Smith and Read 1997; Richardson 2001) [71, 66].

Microbial Biomass

Organic matter is one of the essential components of soil quality that support soil microbial life. The microbial biomass mediates many important functions in soils that include nutrient mineralization, nutrient cycling, and decomposition and formation of SOM as they are the main sources of enzymes in soils (Tabatabai 1994; Acosta-Martinez, Zobeck, and Allen 2004) [75, 2]. Transformation and storage of soil nutrients is regulated by the microbial biomass present, and flow of nutrients through the soil microbial fraction can be substantial (Martens 1995; Prenger and Reddy 2004) [51,60].

Comparative assessment of organic, inorganic and integrated management practices in rice (*Oryza sativa*)-based cropping system in acid soil of Assam

Baishya *et al*. conducted a field experiment from 2008-09 to 2014-15 under All India Coordinated Research Project on Integrated Farming System at Assam Agricultural University, Jorhat, Assam to evaluate the effect of organic (alone), inorganic (alone) and integrated nutrient management on soil properties and productivity.

They found season-wise yield of crops at different phases of crop cycles (such as at initial level, mean yield up to conversion period and after conversion period) as affected by different organic, inorganic and integrated nutrient management practices in case of winter rice–toria–blackgram system under climatic condition of Asom (Table 2) indicated that during the initial year, yield of *kharif*, *rabi*and summer crops were higher with application of 100% recommended dose of nutrients through chemical fertilizers + secondary and micro- nutrient, followed by application of 50% RDF (inorganic) + 50% RDN (organic) as FYM/compost + inorganic sources of micro-nutrient as per soil test. On the other hand, mean yield up to conversion period (1st to 3rd crop cycle) was found to be the highest in treatment receiving both organic and inorganic sources of nutrients. After conversion period, the highest yield of rainy (*kharif*) crop was recorded in 100% NPK doses through organic sources plus intercropping with wheat during *rabi*and okra during the summer season, and the highest yield of winter (*rabi*) and summer were recorded in 100% RDF from organic sources as 1/3 FYM/ compost + 1/3 vermicompost + 1/3 MSC + pumello fruit as bio-pesticide. System-equivalent yield (SEY) calculated at initial level, mean SEY up to conversion period and mean SEY after conversion period of winter rice–toria– blackgram system (Table 1) indicated that initially, the highest (11.19 t/ha) SEY was recorded in 100% RDF as inorganic source + secondary and micronutrient based on soil test, followed by 50% RDF as inorganic source + 50% RDN as organic + inorganic sources of micro- nutrient as per soil test value + pumello fruit.

Table 2: Effect of management practices on crop yield (t/ha) and economics of rice–*toria*– blackgram system on different phases

Treatments	**Initial yield level of winter rice–potato–okra sequence**			**Mean yield of winter rice–potato–okra sequence up to conversion period (from 2005–06 to 2007–08)**			**Mean yield of winter rice–toria–blackgram after conversion period(from 2008–09 to 2014–15)**			**Gross returns (× 103 Rs/ha)**	**Net returns (× 103 Rs/ha)**	**Benefit: cost ratio**
	Rainy Season	**Winter Season**	**Summer**	**Rainy Season**	**Winter Season**	**Summer**	**Rainy Season**	**Winter Season**	**Summer**			
T_1	3.28	9.50	1.02	3.10	6.18	1.52	3.10	0.51	0.50	109.5	63.0	1.58
T_2	2.60	7.76	0.87	2.65	5.91	1.19	3.27	0.52	0.55	96.4	27.0	1.80
T_3 (MC)*	2.76	4.00	0.58	2.66	4.18	0.93	3.48	0.44	0.41	159.9	80.6	2.09
T_3 (IC)**	-	3.00	0.30	-	4.00	0.28	-	1.20	2.58		-	-
T_4	2.82	8.20	0.93	2.66	5.69	1.09	3.21	0.50	0.49	104.2	35.5	2.31
T_5	2.16	7.43	0.69	2.63	4.20	1.03	2.84	0.39	0.44	90.3	57.5	2.45
T_6	2.84	6.80	0.74	2.72	4.12	1.20	3.41	0.38	0.40	101.0	29.0	1.46
T_7	3.56	10.08	1.10	2.57	6.05	1.49	2.96	0.42	0.48	109.5	57.0	1.26
SEm±	-	-	-	0.23	0.30	0.11	0.20	0.03	0.02	-	-	-
CD (P=0.05)	-	-	-	0.72	0.87	0.33	0.70	0.07	0.06	-	-	-

Table 3: Post-harvest soil properties under various management packages in rice–*toria*–black gram systems (data given are mean-value of 7 years from 2008–09 to 2014–15)

Treatments	**Bulk density(Mg/m^3)**	**Aggregate size (mm)**	**Infiltration Rate(mm/hr)**	**Water Holding Capacity (%)**	**pH**	**Electrical Conductivity (dS/m)**	**Soil Organic carbon (%)**
T1	1.22	0.74	5.5	53.01	5.15	0.173	0.71
T2	1.19	0.78	6.2	57.28	5.30	0.180	0.76
T3	1.19	0.80	6.3	58.98	5.29	0.194	0.88
T4	1.21	0.79	6.2	57.20	5.26	0.146	0.76
T5	1.23	0.72	5.6	46.00	5.29	0.079	0.76
T6	1.21	0.81	5.8	60.00	5.24	0.140	0.79
T7	1.23	0.68	4.9	49.98	5.03	0.292	0.70
Initial value	1.21	-	-	47.15	5.05	-	0.66
SEm±	0.01	0.003	0.02	0.65	0.01	0.003	0.08
CD (P=0.05)	0.027	0.009	0.05	1.36	0.03	0.008	0.18

T1-50% RDF (inorganic) + 50% RDN (organic) as FYM/compost + inorganic sources of micro-nutrient as per soil-test value
T2-100% RDF (organic) as 1/3 FYM/compost + 1/ 3vermicompost + 1/3 MSC
T3-T 2+ wheat and okra as intercrop during winter and summer season respectively
T4-T2+ manual and mechanical weeding
T5-50% RDN (organic) as FYM/compost + Azospirillum/Azotobacter + 50% P as rock-phosphate + PSB
T6-T2+ Azospirillum/Azotobacter + PSB + Pumello fruit (Bio-pesticide)
T7-100% RDF (inorganic) + second- ARY and micronutrient based on soil test value

In Table 2 and table 3 they found significant changes were recorded in different properties of soil under organic, inorganic and integrated management practices (Table 3). Decreasing trends in bulk density of soil were recorded from the initial value in all the treatments. The lowest soil bulk density was recorded in treatment receiving 100% NPK through organic sources of nutrients. Soil aggregate sizes were varied between 0.68 and 0.81 mm. The highest increase (19.12%) in aggregate size of soil was recorded in treatment receiving 100% NPK through organics (1/3 FYM + 1/3 vermicompost + 1/3 MSC) plus *Azospirillum/Azotobacter*+ PSB application, whereas the lowest in case of 100% RDF as inorganic source + secondary and micronutrient application based on soil-test value. Infiltration rate of water was found to be highest in 100% NPK doses through organic sources plus intercropping with wheat during the winter (*rabi*) and okra during the summer season, followed by 100% NPK supplied as 1/3 FYM + 1/3 vermicompost + 1/3 MSC and T2+ manual and mechanical weeding. Water holding capacity of soil was increased over initial value (47.2%) in all the treatments under study except 50% RDN (organic) as FYM + *Azospirillum/Azotobacter*+ 50% P as rock-phosphate + PSB treatment. The Highest increase (27.3%) in water holding capacity of soil over initial was observed when 100% recommended dose of NPK was supplied through organics as 1/3 FYM + 1/3 vermicompost + 1/3 MSC along with *Azospirillum/Azotobacter*+ PSB application. Changes in soil *p*H and electrical conductivity (EC) during 2008–09 to 2014–15 as affected by different organic (alone), inorganic (alone) and integrated use of nutrient sources in case of winter rice-toria-blackgram system in acid soils of Asom (Table 3) indicates that soil *p*H was the highest (5.30) when 100% NPK were supplied as 1/3 FYM + 1/3 vermicompost + 1/3 MSC, whereas the lowest (5.03) was recorded in 100% recommended dose of nutrients through chemical fertilizers.

Function of organic matter (green manure) and the effect on soil properties

Vaidya *et al.*, 2009 [80] conducted a field experiment in Chalnakhel forest in central Nepal.This forest is situated in southern part of Kathmandu valley 12 km. South of Kathmandu City near to Pharping. Study site was newly planted but there were too many spaces for plantation.

Table 4: Nutrient analysis of Organic matter and soil

Sample type	pH	Total N%	Available P kg/ha	Available K kg/ha	Organic matter %
Tithonia diversifolia	-	33.2	2.8	34.1	29.87
Lantana camara	-	28.6	1.7	12.2	29.95
Eupatorium adenophora	-	36.7	2.6	22.6	14.94
Soil before plantation	7.3	0.12	6.0	94.0	1.81
Soil after plantation	8.2	0.5	33.4	188.0	2.93

Table 5: Average height of the plant

No.	Treatment	Avg. plant height (mtr)
1.	Plantation of nursery plant with *Lantana camara*	2.5
2.	Plantation only nursery plant without *Lantana camara*	0.62

Table 6: In this the soil with organic matters (Lantana camara) had many spores and control had only few

No.	Treatment	Spores present in 25 gms. of soil
1.	Plantation of nursery plant with *Lantana camara*	250
2.	Plantation only nursery plant without *Lantana camara*	50

They find that after one year all these plantations were harvested. Among control five plants were died due to poor soil quality and low organic matter but with organic matter all the plants were survived. The height of plants were measured control as well as with organic matter. Before field experiment number of spores per 25gms. of soil have only 40 spores in average. In this *Glomus* species were more than that of *Acaulospora* species. After harvest average number of spores in control was 50 and with organic matter number of spores was present 250 per 25 gms. of soil Table 6. In this five-species were found such as *Glomus Macrocarpum, Glomus constrictum, Acaulospora Spinosa, Acaulospora scobitulata and Acaulospora spinosa.* Average height of the plant with organic matter was 2.5 mt. and average height of plant in control was only 0.62 mt. Table 5.

Soil organic carbon, biological properties and plant biomass as affected by application of organic manures in tea

Rajkonwar *et al.*, 2016 [61] conducted a pot culture experiment using the soils collected from AAU tea garden (Jorhat district) and Negheriting Tea Estate (Golaghat district) of Assam, India during 2011-12.

A pot culture experiment was carried out to understand the effect of different organic manures on soil properties of tea garden soils and biomass yield of tea plant in the year 2010 at Department of Soil Science, Assam Agricultural University, Jorhat, Assam (India). The soils of upper 0 to 15 cm depth were collected during winter season from two tea gardens *viz.* from the Experimental Tea Garden of Assam Agricultural University (AAU), Jorhat and from the Negheriting Tea Estate of Golaghat district of Upper Brahmaputra Valley Zone of Assam. There were 4 treatments *viz.* T1: Control; T2: Compost; T3: Biogas digester slurry and T4: Vermicompost and thus, there were 8 treatment combinations using the soils collected from AAU tea garden of Jorhat district and Negheriting Tea Estate of Golaghat district, separately. Each treatment combination was replicated three times in Factorial Randomized Block Design. Therefore, for the pot culture experiment, 24 numbers of earthen pots were arranged. Each pot was filled with 1.8 kg dry soil and the organic manures were added into each of the pot at the rate of 2.5% of the total soil used.

Table 7: Effect of organic sources on organic carbon, humic acid and fulvic acid in case of tea soil

Treatments	Soil organic carbon (%)			Humic acid (%)			Fulvic acid (%)		
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
T_1	0.98	1.30	1.14	0.33	0.57	0.45	0.55	0.76	0.66
T_2	1.21	2.17	1.69	0.96	1.21	1.09	0.86	1.14	1.00
T_3	1.43	2.08	1.75	0.96	1.15	1.06	0.87	1.13	1.00
T_4	1.22	2.18	1.70	0.98	1.20	1.09	0.87	1.13	1.00
S.Ed.±	-	-	0.06	-	-	0.02	-	-	0.01
CD-5%	-	-	0.12	-	-	0.03	-	-	0.02
T1-Control					S1-Experimental Tea Garden of AAU, Jorhat				
T2-Compost									
T3-Biogas digester slurry					S2-Negheriting Tea Estate of Golaghat district				
T4-Vermicompost									

They conclude that SOC content increased significantly in the soils that had received organic sources *viz.* compost, biogas digester slurry and vermicompost over the control treatment. Application of biogas digester slurry showed the highest increase in SOC in case of the soils collected from the Experimental Tea Garden of AAU, Jorhat district; whereas SOC increase was highest due to application of vermicompost in case of soils collected from the Negheriting Tea Estate of Golaghat district of Assam. When different types of organic manures were applied, there were 190.90 – 196.97% and 101.75 – 112.28% increase in humic acid over control was recorded in the soils collected from AAU Experimental Tea Garden (Jorhat district) and Negheriting Tea Estate (Golaghat district) of Assam, respectively. Same trend was also followed in case of fulvic acid; where 56.36 – 58.18% and 48.68 – 50.00% increase in fulvic acid was recorded in case of the soils collected from AAU Experimental Tea Garden (Jorhat district) and Negheriting Tea Estate (Golaghat district) of Assam, respectively. However, the mean data (in Table 3) showed 142.22 and 51.52% increase respectively in humic and fulvic acid content in tea soils when different types of organic manures were applied over control.

Conclusion

- SOM is understood today as the non-living product of the decomposition of plant and animal substances
- SOM tightly controls many soil properties and major biogeochemical cycles its status is often taken as a strong indicator of fertility and land degradation
- SOM can be considered as the building block in maintaining the sustainability of cropping pattern as it influenced the physical, chemical and biological property of soil
- SOM in forest and in turn contribute to the development of a healthy and sustainable soil and as well as environment.

Future prospects

- Deteriorating soil quality, health hazards and declining factor productivity are major concerns of Indian agriculture today. Thus, organic soil management is slowly becoming a necessary compulsion not only for organic conversion but also to restrict productivity depletion under chemical farming practice.
- The potential of green manures to affect P fertility of succeeding crops in temperate regions has remained largely has not yet been investigated.
- The steady decline in soil organic matter levels due to continuous cropping without recycling enough crop or animal residues, coupled with nutrient imbalances due to insufficient application of nutrient has led to negative nutrient balance in agriculture, impaired soil health and declining factor productivity. Thus further study on role of organic matter in maintaining sustainability of cropping system is necessary.
- Socio-ecological constant need to be mitigated in order to increase the adoption of compost technology at the large scale leading to zero wastes.

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