Effective management practices for improving soil organic matter for increasing crop productivity in rainfed agroecology of India

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To meet the requirement of increasing demand for food and fodder and to ensure food security, it is important to increase the production potential through soil health improvement in rainfed agroecological regions besides the irrigated regions. Degrading soil health because of decrease in soil organic carbon (SOC) and resultant decline in overall soil fertility in rainfed areas is a major threat to sustenance of crop and fodder productivity. In view of the importance of soil organic matter (SOM), and its close relationship with soil health and crop production, its role in carbon sequestration and nutrient cycling has gained much attention in the last few years. Restoration of SOM contents in the soil to optimal levels will not only improve the soil health of rainfed agroecosystem, but will also significantly contribute towards boosting crop production. In this article, we have critically reviewed the impacts of different crop management practices on SOC content and its impact on soil health and crop productivity in rainfed agroecological regions of the country.

Keywords: Crop production, rainfed agroecology, soil organic matter, soil health improvement.

SOIL organic matter (SOM), affects several soil properties which are important for maintaining the productivity of soils on a sustainable basis. It has been considered as a life-line to the soil, which significantly affects water-holding capacity, cation exchange capacity (CEC), aggregate stability, buffering capacity, salinization and sodification, acidification, etc. Besides these, it is an important factor in determining nutrient cycling and its supply to the plants, especially nitrogen, phosphorus, sulphur and micronutrients. In the rainfed agroecological regions of India, the soils are highly diverse and comprise of Vertisols and Vertic sub-groups, Alfisols, Oxisols, Inceptisols, Aridisols, Entisols, etc. Each rainfed soil order has some inherent problem in supporting crop productivity. Moisture stress, subnormal permeability, nutrient fixation (P-fixation), erosion, poor nutrient retention and slope are the predomonant soil health constraints in the rainfed regions. Furthermore, there exists a large variation in rainfall which ranges between 400 and 1500 mm per annum. There is also large variation in the length of the growing period (LGP), which ranges between 60 and 180 days, and sometimes even lower in rainfed agroecology of the country. On the basis of predominant crops grown in specific areas, the rainfed agroecosystem of the country comprises five production systems which include: rainfed rice, nutritious (coarse) cereals, oilseeds, pulses and cotton-based systems. These five production systems have a greater impact on the socio-economic status at individual state level and also at the country level owing to the involvement of large areas and greater number of farmers[1]. Poor organic matter status of soils in rainfed agroecosytem, particularly in arid, semi-arid and sub-humid climate, is a major factor responsible for poor soil health and low crop productivity[2,3]. Also, simultaneously, maintaining or improving SOM levels in soils of the rainfed agroecosystem, particularly in arid, semi-arid and sub-humid climate is difficult because of high rate of oxidation under prevailing high temperatures. This situation is further aggravated by the faulty soil–crop management practices in these areas. Moreover, due to poor socio-economic status of the farmers, SOM is only a major source of plant nutrients in these regions. In addition, it has been proved that SOM is closely linked to the nutrient use efficiency and deficiency of the other plant nutrients in rainfed agroecology[4–7]. It is not an exaggeration to emphasize here that in the absence of appropriate soil management practices, other agricultural technologies (new breeding technologies, development of genetically modified crops, precision agriculture, fertilizer response, etc.) would not add value in these regions. Therefore, appropriate management of SOM is an important and necessary prerequisite for improving and sustaining crop productivity and restoring soil health in rainfed agroecosystem.

Soil organic matter status and its causes of decline

As a fundamental principle, soils of different agroecological sub-regions (AESRs) will show variation in soil

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Table 1. Soil organic carbon content at 0–15 cm soil depth at different locations under predominant rainfed crop production systems

Soil order and soil sampling locations*	Organic carbon content (g kg^{-1}) in soil at 0–15 cm depth
Inceptisols (Varanasi, Faizabad and Uttar Pradesh (UP); Agra; Ballowal-Sauntri, Punjab; Rakh Dhiansar, Jammu and Kashmir; Jhansi, UP)	4.62
Alfisols/Oxisols (Phulbani, Odisha; Ranchi, Jharkhand; Ananthpur, Andhra Pradesh; Bengaluru, Karnataka)	3.18
Vertisols/Vertic group (Rajkot, Gujarat; Indore and Rewa, Madhya Pradesh and Akola, Maharashtra; Kovilpatti, Tamil Nadu; Bellary and Bijapur, Karnataka; Solapur, Maharashtra; Arjia, Rajasthan)	3.92
Aridisols (Hisar, Haryana; SK Nagar, Gujarat)	2.10

*Dominant crop production system at Varanasi, Faizabad, Phulbani and Ranchi is rice-based; at Agra, Hisar and SK Nagar is pearl millet-based; at Ballowal-Sauntri, Rakh Dhiansar and Arjia is maize-based; at Jhansi is rabi-sorghum-based; at Anantapur and Rajkot is groundnut-based; at Bengaluru is finger millet-based; at Indore and Rewa is soybean-based; at Akola and Kovilpatti is cotton-based and at Bellary, Bijapur and Solapur is rabi sorghum-based.

reactions, base saturation, nutrient-holding capacity, organic matter content and LGP to sustain agricultural and horticultural crops grown in the respective regions. Srinivasarao *et al.*[8] showed that the organic matter status of different locations in rainfed agroecology was very low (Table 1). The soil organic carbon (SOC) content assessed under different crop production systems in rainfed agroecology regions was found to be below 5 g kg^{-1} soil in majority of the cases. Researchers have also reported that soils under different states of India representing rainfed crop production systems are severely deficient in organic carbon content in the topsoil layer (0–30 cm). In some of the rainfed agroecology regions, SOC was found to be as low as 0.15% (refs 7 and 9).

There are several climatic and social factors responsible for poor organic matter status of these soils, viz. erratic weather patterns, particularly high temperature leading to higher rates of oxidation of SOM; loss of top fertile layer by erosion; slopy land; low income of farmers resulting in low fertlizer use and consequent low biomass production; huge knowledge gap; under-utilized resource capacity, etc.[10]. Apart from these, faulty soil and crop management practices such as low level of organic inputs, imbalance in nutrient supply, frequent tillage practices, etc. are also responsible for decrease in SOC content in these areas. Thus, if we adopt proper soil–crop management practices, the decline in organic carbon content can be prevented and crop productivity can be enhanced significantly.

Role of SOC in soil health maintenance

It is well established that SOC plays a crucial role in the maintenance of majority of soil properties for better crop production and soil health. SOM significantly affects water-holding capacity, aggregate stability, and compaction and strength characteristics of soils. It also improves aggregate stability and tends to reduce water erosion. As the size of the aggregates reduces to less than 850 μm, they become more susceptible to erosion caused by wind and water. Researchers have reported a negative relationship between organic matter content and bulk density of soils, which is useful in crop production[11,12]. Bandyopadhyay *et al.*[13] reported that the use of organic matter (FYM @ 4 t ha^{-1}) in combination with recommended levels of inorganic fertilizers resulted in a decrease in bulk density (9.3%), soil penetration resistance (42.6%) and an increase in hydraulic conductivity (95.8%), size of water-stable aggregates (13.8%) and SOC (45.2%) compared to control. It has been shown that thermal heat properties of soil related to storage and heat flow through it are also influenced by SOM[14].

Similarly, SOM is a major factor in regulating the cycling of nitrogen, phosphorus and sulphur, and their supply to the plants. It is well understood that different soil organic fractions have varying properties and so is their influence on different soil properties. For example, humus fraction plays an important role in chemical activity such as CEC of the soil, pH and buffering capacity. Similarly, particulate organic carbon is important for maintaining aggregate stability and nutrient recycling, and acts as a source of food and energy for various soil microorganisms. Humus also regulates the retention and release of plant nutrients, as it has a negative charge. The importance of organic matter content of the soil also lies in the fact that it is helpful in predicting CEC of the soil. It is an established fact that organic matter contributes 25–90% of CEC of a soil. The contribution of organic matter towards CEC of the soil depends on several factors such as parent material, quality and amount of organic matter and management pattern of the soil. It has been observed that contribution of SOM towards CEC in sandy forest soils is more than in Vertisols derived from basaltic parent material. A study has reported greater association between CEC and pH, and has revealed a significant role of organic matter in enhancing CEC[15]. The contribution of organic matter towards CEC at pH 3.5 was found to be 28%, but at pH 7.0, it was 40% (ref. 15). Some studies have revealed that buffering capacity of the soil is an important parameter for soil health, as it resists abrupt changes in soil pH and prevents its decline[16]. Besides pH, and type and amount of clay, SOM is one of the most effective factors which buffers the soil against changes in pH. It is found that in acidic and highly weathered soils rich in kaolinite and illite, and oxides and hydroxides Fe and Al, SOM assumes greater importance to buffer the soil against changes in pH. Swarnam and Velmurugan[17] reported that in a strongly acidic sandy loam soil (pH_{CaCl_2} 4.19) of Port Blair, application of different organic sources improved many soil chemical properties. Researchers have reported that combined application of the organic sources, bio-inoculants and gypsum brought about significant positive changes in different soil properties[18–21].

Organic matter also plays a key role in the growth and proliferation of soil biota. Decomposition of organic matter in the soil helps the soil microorganisms by providing them energy and carbon for the formation of new cells. Microorganisms are friends to the soil and are essential for soil ecosystem functions. They help in biochemical recycling of nutrients in the soil by way of inter-conversion of different forms of nitrogen, sulphur and phosphorus, associated with the carbon cycle. Huge populations of microorganisms are found in the soil, but the microbial biomass constitutes only a small fraction of SOM (<5%), and is dynamic in nature. Experiments conducted by Das and Dkhar[22] revealed that addition of organic fertilizers increased the fungal and bacterial populations compared to NPK and control. It also resulted in improvement in physico-chemical properties of the rhizosphere soil compared to NPK and control plots (Figure 1). The foregoing information indicates that the use of organic fertilizers would help sustain soil fertility on a long-term basis and in meeting the present and future demand for food and fodder.

Management practices for improving SOC and crop productivity

Improved soil–crop management practices significantly enhance SOC in rainfed agroecology of the country. Some of the prominent soil–crop management practices have been described here in detail for improvement of soil health and crop productivity in rainfed agroecological regions.

Integrated nutrient management

The importance of integrated nutrient management has been well-documented by Katyal *et al.*[23], with continuous application of chemical fertlizers to virgin soil, SOC remained stable for 10 years, while in manure and fertilizer (integrated nutrient management) practices, it was stable for 25 years. This indicated that combined use of organic and inorganic fertilizers played an important role in stabilizing and maintaining SOC in cropping systems and ensuring sustainability. Various studies conducted in rainfed agroecology revealed that there was a direct positive relationship between profile SOC content, and crop productivity and soil health[24–27]. Results of various long-term experiments conducted at different rainfed locations by Srinivasarao *et al.*[28–33] and Sharma *et al.*[34,35] in different cropping systems (groundnut production system[28], finger millet-based production system[29], groundnut–finger millet[30], pearl millet–cluster bean rotation production system[31], safflower and soybean-based production system[32], sorghum-based production system[33], pearl millet production system[34], sorghum–mung bean-based production system[35], proved that integrated nutrient management significantly enhanced SOC and associated soil function, and crop productivity significantly in different rainfed agroecology of India. These results further suggested that in rainfed agroecology, long-term application of chemical fertilizers could not maintain optimum soil carbon content and crop productivity[28–35]. On the other hand, the sole use of organic fertilizers also could not maintain the desired agronomic productivity in these areas due to inherently low nutrient status of these soils. Therefore, the application of recommended dose of the chemical fertilizer coupled with organic fertilizer is important for these areas[36]. Other researchers have also emphasized the role of integrated use of organic and inorganic sources of nutrient management practices in the improvement of SOC and crop productivity in rainfed agroecology. Sharma *et al.*[37] showed that integrated nutrient management practices, viz. 2 Mg *Gliricidia* loppings + 20 kg N and 4 Mg compost + 20 kg N proved most effective in enhancing sorghum grain yield to the extent of 85% and 78% over control respectively. In this study[37], the highest amount of SOC at 0–15 cm soil depth (0.74%) was recorded in 100% organic treatment (4 Mg compost + 2 Mg *Gliricidia* loppings). Some of these nutrient management options can be used even as a component of organic farming.

Addition of organic amendments

The prevailing high temperature and frequent inversion tillage practices result in fast oxidation of SOM leading to decline in its status in tropical rainfed regions. This in turn calls for frequent supply of organic amendments to the soil. Regular applications of different organic sources to the soil help in progressively enhancing the organic matter status in the soil and also supplies essential nutrients to plants. There are various options available to the farmers for on-farm generation of organic sources of

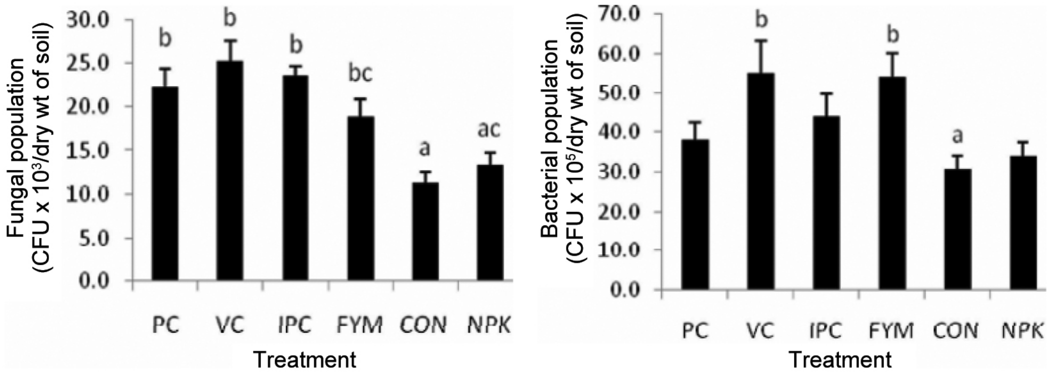

Figure 1. Effect of organic and inorganic fertilizer treatment on rhizosphere microbial community (fungi and bacteria). Mean ± SE with the same letter on top does not differ significantly, whereas different letters on top indicates significant difference according to Tukey's test (ANOVA; $P = 0.05$). PC, Plant compost @ 15 t ha^{-1}; VC, Vermicompost @ 7.5 t ha^{-1}; IPC, Integrated plant compost @5 t ha^{-1}; FYM, Farmyard manure @ 15 t ha^{-1}; CON, Control, and NPK, in the ratio 10 : 30 : 20 kg ha^{-1} in soybean crop[22].

nutrients, viz. crop and weed residues and their composting, vermicomposting, green manuring through crops, tree-based green leaf manuring, tank silt application, application of FYM, poultry manure, and sheep and goat manuring to increase SOC content and crop productivity in rainfed agroecology. Some off-farm sources such as treated sewage sludge, biochar and agro industries waste (baggessage, coir pith, groundnut shell, poultry manure, sheep penning, press mud, seri waste, etc.) can also be used as a sources of the organic matter in this zone. Over the years, organic amendments have become the key factors for maintaining soil health and crop productivity in the country.

Addition of crop and weed residues

Incorporation of crop residues using suitable machinery or retaining them on the surface of the soil considerably enhanced SOC content of rainfed agroecology. Sharma *et al.*[37] showed that regular application of crop residues of sorghum and *Gliricidia* lopping on the soil surface improved SOC and many other associated soil functions as well as yield of sorghum and castor in rainfed agroecology under different tillage systems (conventional tillage system and minimum tillage). Researchers have also emphasized the role of surface spreading of weed residues in improving SOC and crop yield in rainfed agroecology[38–40]. The surface residues work in three ways: (i) they protect the soil surface from excessive heating by solar radiations by providing a cover; (ii) they do not allow the raindrops with high potential energy to fall directly on the soil, leading to reduction in erosion, and (iii) they give more opportunity to rainwater to filter into the soil. Besides these benefits, after decomposition, residues help in supplying different nutrients in the soil. Similarly, the biomass/residue of many weed species (viz. *Parthenium hysterophorus*, *Eichhornia crassipes*, *Trianthema portulacastrum*, *Ipomoea*, *Calotropis gigantea*, *Cassia fistula*) can also be used as a source of C and nutrients in rainfed agroecology for improving different soil properties as well as the overall soil health and important soil functions.

Cover crops

The autumn and spring crops grown as cover crops, when incorporated in the soil can help in building or maintaining SOM. The best results of raising these crops can be achieved if other remedial practices such as *in situ* moisture conservation are also adopted. Results of the long-term experiments in rainfed agroecology suggested that *in situ* incorporation of fresh biomass of horse gram (*Macrotyloma uniflorum*) with different levels of fertilizers over a period 10 years, increased the organic carbon and microbial biomass carbon by 24% and 28% respectively, compared to fallow plots. These practices also helped in increasing soil fertility. When N and P were applied alone, a negative balance of soil K was recorded. Based on long-term data, it was observed that application of crop residue in combination with inorganic fertilizers stabilized the yield of sorghum over a period of 10 years. However, the sole application of fertilizers maintained a declining trend in the yields of sorghum and sunflower crops[41]. Results clearly showed that in rainfed agrecology, growing of cover crop and its mixing in the soil could be one of the important crop management strategies in these areas to improve organic matter and crop productivity. Mohanty *et al.*[42] found a significant increase in SOC due to residue application to soil and also protecting it as cover under the minimum tillage in maize + cowpea intercrop and a follow-up cover crop (toria mustard and horse gram). This practice played a significant role in improving the status of CEC ($r = 0.57^{**}$), base saturation ($r = 0.54^{**}$), available N ($r = 0.77^{**}$), P ($r = 0.47^{*}$) and K ($r = 0.63^{**}$) (**indicates significance at $P = 0.01$ and *indicates significance at $P = 0.05$.). From these results, it was inferred that maize–cowpea intercrop with minimum tillage during *kharif* season (wet season) and growing of horse gram as cover crop on stored moisture or with off-season rainfall (dry season) was an effective practice in restoring the soil health of the erosion susceptible sloppy terrains in North Central Plateau zone of Odisha, India.

Crop production system/cropping system

Adoption of appropriate crop rotation/sequence plays an important role in increasing SOC and in amending other associated properties of the soil. Srinivasarao *et al.*[28–33] have comprehensively documented the potential of different crop production systems in enhancing the SOC content under rainfed agroecological conditions. They have concluded that soybean-based production system contained higher stocks of SOC (62.3 Mg C ha^{-1}), followed by maize-based (47.6 Mg ha^{-1}) and groundnut-based (41.7 Mg ha^{-1}) cropping systems. Soils under pearl millet- and finger millet-based systems contained relatively lower SOC stocks. Moreover, they have found a highly significant positive correlation between sustainability yield index (SYI) and stock of SOC in groundnut ($R2 = 0.93$, $P < 0.001$), finger millet ($R2 = 0.93$, $P < 0.001$), finger millet monocropping ($R2 = 0.90$, $P < 0.01$), and sorghum ($R2 = 0.81$, $P < 0.01$). However, these relationships were weak in groundnut monocropping, pearl millet, cluster bean, castor, safflower, rice and lentil[25]. Thus, the ongoing crop production of a particular region significantly improves the organic carbon status and crop productivity. Depending upon the circumstance, inclusion of grasses in the crop production system may help in restoring the organic matter status. Similarly, growing of leguminous crops in crop rotation has a potential to improve crop yield, enhance soil quality and maintain sustainability across the rainfed agroecologies. In every crop season, there is a need to maintain at least 40% legume component. In rainfed agroecology, where organic matter is very low, one of the important remedies is to return the land to permanent pasture to build up organic matter.

No or minimized tillage in the crop production system

Tillage is an important factor leading to the loss of SOM. Besides, it changes the environment of the soil[43,44]. When the soil is tilled repeatedly, it gets aerated and consequently microbial activity in the soil is increased and the process of organic matter decomposition is accelerated. It is well established that organic matter decomposition and consequent emission of CO_2 are aerobic processes; the oxygen accelerates the microbial activity. Besides this, tillage often increases wind and water erosion, which in turn sweep away organic matter from the soil. Thus minimum-tillage and no-till systems alone play a major role in reducing the rate of decline in SOC. When tillage is combined with other practices (viz. straw incorporation, green manure, organic matter incorporation, etc.), it helps maintain or increase organic matter status of the soil. Numerous studies from the rainfed agroecology of India reveal that the minimum tillage practices coupled with crop residues incorporation improve SOC content and crop productivity[26,45–47]. *Lantana camera*, an obnoxious woody weed has been successfully used for field application in rainfed agroecology of Himachal Pradesh[38–40]. Minimum tilled and fully covered straw mulched plots provided the best straw and grain yield in rainfed regions of Punjab[45,47–49].

Incorporation of green manuring crops

It is well established that incorporation of biomass of green manuring crops in the soil enhances the SOC and other nutrients, especially nitrogen, irrespective of the cropping system under different climatic conditions[50]. The prominent green manuring crops in different rainfed ecology are sunhemp, dhaincha, cluster bean, Sesbania, cowpea, green gram, etc., as these crops are leguminous in nature and have good potential to fix atmospheric nitrogen in the root nodules. Majority of the studies on this aspect have been carried out under irrigated ecology. The results of these studies revealed that there was a tremendous potential to increase SOC content and improve other associated soil functions using different green manuring crops, paticularly dhaincha and sunhemp. Some studies have indicated considerable improvement in the activities of various enzymes (dehydrogenase and phosphatase activity) with green manuring using sunhemp, green gram and cowpea crops compared to control. A significant build-up of N, P and K was also observed with green manuring crop. Several other studies have indicated the benefit of green manuring in rainfed regions[51–53].

Mulch-cum-manuring with tree leaf

The green leaf manuring species adapt well in different types of soil, and play an important role in enhancing soil fertility and productivity. Some of the tree species such as *Pongamia glabra*, *Azadirachta indica*, *Delonix regia* and *Peltophorum ferrugenum* are easily grown in different regions of the country, and their leaves could be used as the mulching material in the rainfed agroecology as a source of organic matter. Besides this, these materials after decomposition can easily provide sufficient quantity of plant nutrients such as N, P and K to the growing crop. These trees and bushes can be grown on the boundary and bunds of fields. It has been shown that tree green leaf manuring with the loppings of *Gliricidia sepium* is a climate-friendly and cheaper technology. In rainfed situation, besides providing green biomass, gliricidia can be used as insecticide, repellant and rodenticide. The other important feature of gliricidia is that it can be easily grown in dry, moist and acidic soils and even under marginal degraded lands. The adoption of green leaf manuring is one of the important options for enhancing the organic matter status of the soil. The degraded soils of the tropics and semi-arid tropics are universally low in available soil nitrogen (N). Raising of gliricidia shrubs on field bunds has three distinct advantages: (i) it is rich in N and can be used to supplement inorganic N; (ii) as such, it stabilizes the bunds, and (iii) when its biomass is used as mulch, it helps in conserving moisture and reducing losses due to soil erosion[54]. Prihar *et al.*[49] have emphasized that mulching with basooti leaves and twigs (*Adhatoda vasica*) is useful for raising the dryland wheat crop. When compared with application of FYM and fertilizer and control, green leaf manuring with *Gliricidia* resulted in a one and a half and threefold increase in castor productivity respectively. Different studies have revealed that yield responses to the application of green leaf manuring with *Gliricidia* have been positive in finger millet in red soils (Karnataka), groundnut in red soils (Andhra Pradesh), pearl millet in light textured soils (Gujarat) and sorghum in medium to deep black soils (Maharashtra). There are reports that in acid red and lateritic soils of Bhubaneswar (Odisha), maize yield increased from 1.7 to 2.1 Mg ha^{-1} with the use of *Gliricidia* leaf manuring (equivalent to 20 kg N ha^{-1})[55]. Sharma *et al.*[46] based on the long-term study, reported that the integrated use of urea and organic N through loppings of leucaena and *Gliricidia* (1 : 1 ratio on N equivalent) resulted in a sorghum grain yield in the range 1.69–1.72 Mg ha^{-1} respectively. Based on this study, they concluded that about 50% of N demand of sorghum crop can be met through these farm-based organic resources. In another long-term study conducted on integrated nutrient management in Alfisol soils, it was found that sorghum and green gram yields were significantly higher with the addition of 1–2 Mg ha^{-1} green loppings of *Gliricidia* along with 10–20 kg N ha^{-1} through urea. Thus, based on these findings, there is a possibility to substitute 50% of fertlizer N with cheaper farm-based organic sources of N, and the expenditure on fertlizer can be reduced substantially.

Biofertilizers

Over the years, researchers have reported on the beneficial effect of biofertilizers in Indian agriculture, irrespective the crop production system[56–60]. The proper use of biofertilizer in rainfed agroecology could be a viable approach to increase crop yield and improve soil health. The effect of added biofertilizers could be enhanced along with chemical fertilizers and different organic sources[60]. Based on INM trials conducted in mulberry in rainfed agroecology[61], it was found that the conjunctive use of poultry manure with *Azotobacter* biofertilizers helped in reducing the doses of inorganic fertilizers, which in-turn had a significant effect on plant growth and the quality of mulberry plants. Sudhakar and Sudha[62] reported that seed inoculation with *Azospirillum* alone resulted in enhanced growth in terms of plant height and other yield-attributing characters and was on par with 50% recommended inorganic N application. Seed inoculation with *Azospirillum* both alone and in combination with 50% recommended inorganic N resulted in on-par seed yield compared to the treatment with 50% N and 100% inorganic nitrogen respectively. Researchers have also observed the beneficial effect of biofertilizers on several rainfed crops (maize and sorghum, bajra, safflower, foxtail millet).

Tank silt application

The application of tank silt in degraded soil of Andhra Pradesh resulted in a significant response of maize and castor in terms of enhancing crop yield besides improving soil physical, chemical and biological properties[25]. The quantitative analysis of different tank silt samples from Warangal districts, Telangana revealed that the content of organic carbon in these samples ranged from 0.3% to 1.5%. Besides organic C, these samples also contained the other plant nutrients such as N (328–748), P (5–35), K (271–522), sulphur (12–30), zinc (1.2–5.6) and boron content (0.4–0.8) mg kg^{-1} silt[63]. These authors reported that tank silt application also improved other physical and biological parametres of the soil. Thus, it is important to capitalize such valuable resources for enhancing SOC content and improving other associated properties, besides improving the crops in these areas.

Conclusion

It is a well-established fact that SOM has a close and direct relationship with soil health and crop production, and also plays an important role in carbon sequestration and nutrient cycling. Thus, SOM has gained tremendous importance in Indian agriculture. Due to harsh climatic conditions, improper soil management practices, poor socio-economic status of the farmers and lack of awareness, SOM in rainfed regions of India has declined to a low level, which in turn has resulted in deterioration in overall soil health. Despite having high-yielding cultivars and other available technologies, we are unable to achieve the desired yield targets in different rainfed crops. In this article, we have taken a stock of different relevant options which can help in increasing organic matter status in soils of rainfed region. Some of these options include: integrated nutrient management, addition of the organic amendments, addition of crop and weed residues, cover crops, no or minimize tillage in the crop production system, appropriate crop production system/cropping system, incorporation of biomass of green manuring crops, mulch-cum-manuring with tree leaf, biofertilizers, tank silt applications, etc. If these practices are followed systematically, the organic matter status of soils in rainfed areas can be enhanced on a long-term basis and overall soil functions (soil health) can be significantly improved. As a result, potential of high-yielding varieties/cultivars of crops available in the country can be capitalized and yield barriers in rainfed crops can be broken.

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