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Long-term effect of nutrient management on active organic pools: A review

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Abstract
The effects of long-term fertilization and manuring on active pools of soil organic matter (SOM) have been studied worldwide. The published papers were critically reviewed aimed to assess the effect of continuing nutrient management practices on active organic pool (SOC, WSC, AHC, SMBC and SMBN) and to determine the depth wise distribution of such pool. The published results revealed that cultivation of crops without or imbalance nutrient addition for long run caused depletion of active organic pools, whereas addition of organic manures or inorganic fertilizers occasioned significant buildup of such fractions over unfertilized control. Published documents also suggested that soil depth is inversely related with active organic pool buildup. It may be concluded from this review that improper nutrient management leads decline active pool of SOM and deplete soil quality and hence proper nutrient supply is crucial for stockpile of such organic fraction in soil.

Keyword: Long-term, Fertilization, Manuring, Organic pool, Soil depth.

1. Introduction
India is predominantly an agricultural based country and most of the population depends on agriculture and allied sectors for their survival. Agriculture contributes approximately 13.9% of India's GDP and is known as backbone of Indian economy. The total geographical area of the country is 328.7 mha, of which 140.8 mha is the reported net sown area and 195.2 Mha is the gross cropped area (Anonymous, 2014-15) [1]. Cultivation of wide varieties of crops in various agro-climatic zones has been practicing throughout the country with various cropping systems.

The crop productivity has been boosted as a result of combined effect of various factors such as improved management practices, fertilizer application, insect- pest management, improved cultivar, proper extension activities etc. but in contrast; some side effects has also been witnessed when crop husbandry practiced for long run. These include pest resistance against pesticides, increased cost of cultivation, lower fertilizer response ratio and declined soil fertility. Low soil fertility is generally associated with declined soil organic pools under continuous long-term cropping systems. SOC plays multifunctional roles and improve physical, chemical as well as biological properties of soil. Several studies have been done to assess depleted SOC under long-term intensive agriculture (Dawe *et al*., 2000 [2] and Manna *et al*., 2006) [3] and depleted SOC content might resulted yield declination (Bhandari *et al*., 2002) [4]. Among soil organic pools, the active pools consists labile materials, provide accessible food for microbes and influenced by fresh residue additions and hence may considered as ideal indicator of soil quality.

Thus the published papers were critically reviewed with following objectives: (i) to assess the effect of long-term nutrient management practices on active pools and (ii) to assess effect of soil depth on their concentration in soil. The findings of various investigators are summarized sequentially for better understanding.

2. Long-term effect of manure and fertilization on SOC stock
Long-term application of NPK alone and in integration with farm yard manure (FYM) either improved or upheld the SOC content over initial value, whereas; the unfertilized control led to decline SOC concentration (Manna *et al*., 2005 [5] and Sekhon *et al*., 2009) [6]. This suggested that continuous crop cultivation without nutrient management resulted loss of SOC in soil.

Many research revealed that application of NPK alone enhanced SOC buildup (Bhattacharya *et al*., 2011) [7], while other indicated that NPK alone did not sufficient to increase SOC in soil (Yuan *et al*., 2013[8] and Liang *et al*., 2012) [9]. However, SOC content decreased with application of nitrogen alone (Manna *et al*., 2006) [3] and with phosphorus (Antil and Singh, 2007 [10] and Fan *et al*., 2007) [11] over initial. This proposed that application of primary nutrients is essential for crop nourishment as well as improving C stock in soil. However; the SOC content was greater in organic manure receiving treatments than inorganic fertilizers treatments (Ortas and Lal, 2014) [12]. The published results strongly advocated that incorporation of FYM significantly improved SOC content over all the treatment if applied alone (Liang *et al*., 2012) [9] or in combination with NP (Antil and Singh, 2007 [10] and Liu *et al*., 2013) [13], P only (Lawal and Girei, 2013) [14], NPK (Bhattacharya *et al*., 2011) [7], green manure (Sekhon *et al*, 2009) [6], wheat straw (Fan *et al*., 2007) [11] and mineral fertilizers (Yuan *et al*., 2013) [8]. This may be related with the accelerated crop growth and as a consequence, biomass returned to soil (Ortas and Lal, 2014) [12]. Problematic soils like acid soil, may characterized with lower SOC and thus, application of lime with NPK also enhanced C sequestration in such soil (Manna *et al*., 2007a) [15] for the reason that lime acted as amendment and improved soil condition. Though; no significant effect of fertilizer treatments was also observed by Bado *et al*., (2010) [16]. Like other organic manures, press mud also contributed towards greater SOC accumulation (Sekhon *et al*., 2009) [6].

Beside the treatments, SOC also influenced by soil depth (Venktesh *et al*., 2013) [17] and decreasing SOC with increasing soil depth has been observed by many researchers (Manna *et al*., 2007b [18] and Yang *et al*., 2014) [19]. Fertilization influenced the SOC up to a depth of 30 cm and there were no significant impact in 30-45 cm soil layer (Bhattacharya *et al*., 2011) [7]. It might be related with lower rhizobium activity, less rhizo-deposition and not as much of biomass return to subsoil layers.

3. Long-term effect of manure and fertilization on water soluble C

Water soluble carbon (WSC) is deliberated as most active fraction of soil organic C (Campbell *et al*., 1999) [20] and is sensitive to fresh material addition. Addition of mineral fertilizers also led to increase WSC accumulation, however the extent is low but the integration of fertilizers with pressmud, FYM, green manure and burnt rice husk resulted significantly greater accumulation of WSC over control (Sekhon *et al*., 2009) [6]. Such accumulation may be linked with biomass addition by crop and roots into soil. Some researchers also found significant increase in WSC status due to FYM application over fertilization and control (Liang *et al*. 2012 [9] and Banger *et al*., 2010) [21]. Improvement in WSC content due to application of FYM with NP only has also been recorded by some investigators (Liu *et al*., 2013) [13]. Kumari *et al*., (2011) [22] recorded significant buildup of WSC under application of 100% FYM only while improvement of WSC under Organic and inorganic fertilizer application was also reported by Kaur *et al*. (2008) [23]. As a consequence of intensive and imbalance fertilizer application, depletion in WSC occurred under long-term trials in different cropping systems. Thus application of balance use of fertilizer increase water soluble carbon concentration in soil (Brar *et al*., 2013) [24]. Due to application of any of the fertilizer or manure, the plant biomass increased which might played vital role in WSC build up in soil.

The vertical distribution of soluble C pool fraction is interconnected closely with washout as water soluble fractions are subjected more to leaching. Accordingly greater WSC builds up with increasing profile depth was observed by Liang *et al*., (2012) [9] and the reason might be eluviation. But in contrast, there is also evidence of greater WSC concentration in surface soil (Sekhon *et al*., 2009) [6] and it may be due to less leaching of soluble carbon. However many of the researchers showed greater accumulation of WSC in surface soil as compare to sub soil (Liu *et al*. 2013 [13], Manna *et al*., 2007a [15], and Sekhon *et al*., 2009) [6] which indicates its response towards soil management and nutrient application.

4. Long-term effect of manure and fertilization on acid hydrolysable carbohydrates

Similar to water soluble carbon, the acid hydrolysable carbohydrate (AHC) is also considered as most active fraction of soil organic matter (SOM) (Six *et al*., 2000) [25]. Thus, it is influenced by several management practices including nutrient management as well. Crop nourishment over long run resulted declined AHC in soil under many soil environments. However; application of balance rate of NPK with or without FYM led to improve AHC content in soil (Manna *et al*., 2005 [5], Kumari *et al*., 2011) [22], though there was less contribution of carbohydrates in inorganic fertilizer amended treatments as compared to organic amendment receiving treatments (Kaur *et al*., 2008) [23]. It may be linked with less above ground return to soil under fertilizer treatments. Application of blue green algae (BGA) or green manure (GM) along with sub optimal dose of NPK showed significant buildup of AHC over control under rice based cropping system (Joshi *et al*., 2015) [26] which might be due to contribution of manure and fertilizers to AHC as well as biomass returned by BGA or GM to soil. Carbohydrate concentration also fluctuates with cropping system, forest system resulted more carbohydrate accumulation than cultivated soil (Spaccini *et al*., 2001) [27], whereas the permanent grassland led to buildup of carbohydrates over forest soil (Guggenberger *et al*, 1994) [28].

Soil depth has negative effect on AHC concentration in soil. The increasing in profile depth leads to decreasing AHC content (Manna *et al*., 2006[3], 2007b) [18] and the reason might be reduced rhizodeposition, lower microbial activities, soil compactness etc.

5. Long-term effect of manure and fertilization on soil microbial biomass carbon

Continuous cropping with imbalance nutrient management practices occasioned reduced microbial activities in soil and hence, lowers soil microbial biomass carbon (SMBC) accumulation. Results obtained from investigations suggested that the SMBC improved when NPK applied alone (Kapoor, 2006) [29] or in combination with FYM (Manna *et al*., 2006 [3], Sekhon *et al*., 2009 [6] and Bhattacharya *et al*. 2011) [7]. Basak *et al*., (2012) [30] reported that the soil amended with value added manure significantly improved SMBC over unfertilized control. However, addition of horse manure compost had also found improvement in SMBC content over control (Zhang *et al*., 2015) [31]. Build up in SMBC content under such organic manure addition might be attributable to increased carbon supply for microorganism. SMBC responded to number of management practices (Schjonning *et al*., 2002) [32] and increased with application of straw inputs in field conditions.

Similarly, like other amendments; biochar application also enhanced SMBC over control (Zhang *et al*., 2014) [33]. Over all, cultivation of crop for long run without or imbalance nutrient management led to decline microbial biomass carbon in soil whereas addition of mineral fertilizer alone or combined with organic amendments resulted buildup of SMBC.

Concentration of SMBC decreased with increasing soil depth (Liang *et al*., 2012) [9] which may be due to less microbiological activities and lack of fresh material addition. However, effect of nutrient management practices in deeper layers was similar to that of surface soil (Liu *et al*., 2013) [13]. Ravindran and Yang, (2015) [34] also reported greater SMBC in organic layer and decreased with profile depth.

6. Long-term effect of manure and fertilization on soil microbial biomass nitrogen

Continuous cropping with long-term nutrient management influenced biomass nitrogen accumulation in soil system. Soil microbial biomass nitrogen (SMBN) varied with seasons, soil depths (Haripal and Sahoo, 2014) [35], treatments and date of observation (Zhang *et al*., 2014) [33]. Significant effect of organic fertilizers on SMBN was reported by Černý *et al*., (2008) [36]. Long-term application of NPK with organic manures resulted improvement in microbial biomass carbon over mineral fertilizer treatments and control (Zhang *et al*., 2009) [37]. FYM had significant effect on SMBN content too when applied with NPK (Manna *et al*., 2007a) [15]. Buildup of such nitrogen might be related with substrate availability and oxygen supply for microbial growth. SOC content also related with microbial population, consequently influenced SMBN content.

Many investigators studied distribution of SMBN in soil profile. Joshi (2015) [26] concluded that the SMBN decreased with increasing soil depth. Similar results were reported by Zhang *et al*. (2014) [33]. This decrement could be related with lower SOC, soil compaction, depleted oxygen content and decreased rhizosphere activity.

7. Conclusion

Results from published papers showed that the continuous crop production without nutrient addition resulted decline soil organic fractions (SOC, WSC, AHC, SMBC and SMBN) whereas balanced nutrient management led to build up of such fractions in soil at upper and lower soil profile depths. The evidenced also revealed that the accumulation of organic pools was more when the organic manures were applied either alone or in combination with inorganic fertilizers. The buildup of soil organic pools was greater in surface soil than subsurface soils.

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