Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(3): 672-674
Received: 03-03-2018
Accepted: 07-04-2018

Sneha Kumari
Department of Agronomy, Institute of Agricultural Sciences, BHU, Varanasi, Uttar Pradesh, India

Swati Swayamprabha Pradhan
Department of Agronomy, Institute of Agricultural Sciences, BHU, Varanasi, Uttar Pradesh, India

Correspondence
Sneha Kumari
Department of Agronomy, Institute of Agricultural Sciences, BHU, Varanasi, Uttar Pradesh, India

Influence of green manuring and straw incorporation on organic carbon pools and productivity of paddy: A review

Sneha Kumari and Swati Swayamprabha Pradhan

Abstract

Soil organic matter is of central importance in maintaining soil quality and is also now receiving attention due to the potential for carbon sequestration in soils. Soil organic carbon (SOC) is one of the main carbon reservoirs in the terrestrial ecosystem. It is important to study SOC dynamics and effects of organic carbon amendments in paddy field. Soil organic carbon pools under long-term management practices provide information on C sequestration pathways, soil quality maintenance, and crop productivity. Farmyard manure (FYM), paddy straw (PS), and green manure (GM) along with inorganic fertilizers were used in rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) cropping system in subtropical India to evaluate their impact on SOC stock, its different pools-total organic C, oxidizable organic C, microbial biomass C and mineralizable C.

Keywords: soil quality, soil organic carbon, carbon pool, manure, paddy straw

Introduction

Globally, soil stores approximately 1,500 Pg of carbon in the form of organic carbon. The soil organic carbon (SOC) pool is 2.5 and 2 times the carbon pool in terrestrial vegetation and the atmosphere, respectively. Thus, small changes in soil organic carbon can cause dramatic changes in the concentration of atmospheric CO_2. Information on organic C stocks in agricultural soils is important because of the effects of SOC on climate change and on crop production. The SOC stock at any time reflects the long-term balance between additions of organic C from different sources and its losses through different pathways. Following the adoption of large-scale intensive cropping, this long-term balance was modified since intensive cropping encourages oxidative losses of C due to continued soil disturbance, while it also leads to a large-scale addition of C to the soil through crop residues. This may cause either a net buildup or a net depletion of SOC stock (Kong *et al*., 2005) [8]. Cropping systems and management practices that ensure greater amounts of crop residue returned to the soil are expected to cause a net buildup of the SOC stock. Identifying such systems or practices is a priority for sustaining crop productivity. To better understand the mechanisms by which C is lost or stabilized in soil, the SOC stock is separated into a labile or actively cycling pool, a slow pool, and a stable or passive, recalcitrant pool with varying residence times. SOC pool is important from the point of view of crop production. It fuels the soil food web and therefore greatly influences nutrient cycling for maintaining soil quality and its productivity (Chan *et al*., 2001; Majumder, 2007) [4, 14]. This pool is also sensitive to land management changes.

Rice–wheat cropping sequence (RWCS) is the world's largest agricultural production system occupies about 13.5 million ha in the Indo-Gangetic Plains of South Asia and provides food for 400 million people and around 85 percent of this area falls in Indo-Gangetic plains (IGP) (Ladha *et al*., 2003) [10]. The crops are grown with adequate amounts of fertilizer and different organics, as available. Several reports, however, have indicated a widespread declining or stagnating trend of yields in the long-term rice–wheat cropping system in Asia. A decrease in SOC has been identified as the major cause for this (Swarup *et al*., 2000; Yadav *et al*., 2000; Ladha *et al*., 2003) [21, 22, 10]. To offset such a decrease (in SOC), different organic amendments such as manure (farmyard manure or green manure), compost, and crop residues (particularly rice straw) are commonly recommended. When applied, a part of their C is stabilized into SOC and distributed among different pools. This process is governed by interplay of factors including climate, substrate biochemistry, C loading, soil, associated precinct, and so on. As such, the different organic amendments are likely to differentially affect the amount of C stabilized and the size and dynamics of SOC pools and ultimately crop productivity. Accordingly, it is hypothesized that the long-term rice–wheat cropping system with balanced fertilization in combination with different organic amendments may influence SOC content, the size of its active or labile pools, and hence the soil quality and sustainable productivity of the system.

Green manuring

Green manuring has been practiced by farmers and accepted as a potential source of organic manure especially in farms where there are not enough animal manures available. However, growing a crop of green manure exclusively for the purpose of green manuring, warrants farmers to set apart land, labour, time and inputs which is considered as a major constraint amongst them. Hence the practice of raising green manure crops as intercrops in rice would be appreciated as a viable alternative to overcome the difficulty. Green manuring can improve soil physical, chemical, and biological properties and consequently crop yields. Furthermore, potential benefits of green manuring are reduced nitrate (NO_3^-) leaching risk and lower fertilizer N requirements for succeeding crops. Continuous cultivation, without application of organic inputs, significantly depleted total C content by 30% when compared with fallow. Application of FYM, PS and GM as a supplement with NPK not only added C to the soil but also increased plant C input in the soil through root residue, stubble, rhizo-deposition (Ghosh *et al*., 2010) [6], Green manuring is considered as an important soil management practice with potential to maintain soil organic matter (SOM) content and to reduce the dependence on mineral fertilizers (Elfstrand *et al*., 2007) [5].

Carbon pools are influenced by increases or decreases in the amount of organic material added to the soil. In cropping systems, labile carbon fractions can be increased by incorporation of cover crops and green manure, which contributes more organic matter than others and provide food for the soil food web and ultimately soil organic matter. Green manure consists of crops grown for ploughing in, thus increasing fertility through the incorporation of nutrients and organic matter into the soil. Leguminous green manures such as clover and vetch contain nitrogen-fixing symbiotic bacteria in root nodules that fix atmospheric nitrogen in a form that plants can use. They are all high in organic carbon and therefore represent additional carbon inputs to the system. Some of these recycled organics also contain a high plant nutrient content and can act as organic fertilizers, reducing the use of inorganic fertilizer. They are important for organic farming systems. Therefore, in this regard a popular term "Regenerative agriculture" which includes maintaining a high percentage of organic matter in soils and minimum tillage, increases biodiversity, minimizes the use of chemical fertilizers, uses composting & green manures & mulching and utilizes crop rotation and cover crops.

Sesbania aculeate was considered to be the premier green manure crop because it fulfills the traits of the ideal green manure for low land rice such as early establishment and high seedling vigour, tolerance to flooding and dry, early onset of N fixation and efficient over varied climate and edaphic conditions, fast growth with an ability to accumulate large biomass and N within four to six weeks of growth and quick decomposability (Ladha *et al*., 1988; Casico, 1990) [9, 3]. Green manuring refers to addition of green plant tissue to soil. Objectives of green manuring are to increase organic matter content of soil, maintain and improve soil structure, reduce the loss of nutrients particularly N, provide a source of N for the succeeding crop and reduce soil erosion and thereby increase the production of crops. Regular practice of green manuring over a long period not only improves the soil fertility but also resulted in noticeable residual effect in intensive cropping system (Palaniappan *et al*., 1990) [16]. Ghosh (2010) [6] reported that the green manure on long term effect results in a very high residual effect than other organic sources.

Straw incorporation

Incorporation of rice straw into paddy soil is another strategy to manage rice straw, but doing it improperly and ineffectively can result in a decrease in production efficiency (Mandal *et al*., 2004, Yadvinder Singh *et al*., 2005) [15, 23] and an increase in greenhouse gas emissions (GHGE) (Sander *et al*. 2014). Loss of soil organic carbon (SOC) from agricultural soils is a key indicator of soil degradation associated with reductions in net primary productivity in crop production systems worldwide (Ramchandran *et al*., 2009). Technically simple and locally appropriate solutions are required for farmers to increase SOC and to improve crop land management. In the last 30 years, straw incorporation (SI) has gradually been implemented across world in the context of agricultural intensification and rural livelihood improvement. Straw has been commonly incorporated to maintain soil fertility and crop productivity, but effects of long-term straw incorporation on crop yield, soil organic carbon (SOC) and total nitrogen (TN) have not been thoroughly evaluated. The effects of straw return on SOC and TN were not significantly affected by experimental duration, land use type and cropping system, but positively and linearly related to the inputs of straw-C and -N, respectively. The management measures that include tillage and straw incorporation not only determine land productivity but also affect soil microbial biomass and activity by altering the temperature and humidity of the soil, the growth stage of the roots, and the quantity and quality of the crop residues, ultimately affecting the content and stability of soil aggregates.

As natural supplements containing valuable nutrients and organic carbon (C), crop straws are often incorporated into soils in sustainable agriculture (Lal 2009) [11]. The practice has some disadvantages, e.g., straw can interfere with crop planting, harbor pathogens or insect pests, and immobilize nutrients from soil and fertilizers (Blanco-Canqui and Lal 2009) [1, 11]. However, straw return is highly recommended to farmers for improving soil structure and preventing decline of soil organic matter (SOM) contents (Lal 2009) [11].

Straw return may increase, reduce or have no significant effects on crop yield, depending on climatic conditions, cropping sequences, tillage, nutrients and water management practices (Pittelkow *et al*. 2015) [17]. Generally, under arid and semi- arid conditions, straw mulching can minimize negative impacts of no-tillage on crop productivity (Pittelkow *et al*. 2015) [17], by improving soil water retention and thus enhancing soil moisture conservation (Blanco-Canqui and Lal 2009) [1, 11]. In subtropical regions dominated by paddy fields, straw retention often leads to sustainable increase in rice yield during the first decade (Huang *et al*. 2013), mainly due to rapid decomposition of the incorporated straw and accompanying nutrient releases, together with beneficial effects on soil physical properties (Yadvinder *et al*. 2005; Powlson *et al*. 2011) [23, 19]. However, in humid temperate regions straw mulching may reduce crop yields by prolonging cold and wet soil conditions in the early growing season (Blanco-Canqui and Lal 2009) [1]. Like crop yield, soil organic carbon (SOC) and total nitrogen (TN) responses to straw return vary widely and are site-specific (Lemke *et al*. 2010; Powlson *et al*. 2011) [12, 19].

Conclusion
Management practices such as application of fertilizer and organic amendments played important roles in maintaining soil quality and C sequestration and thereby greenhouse gas mitigation in the Indo-Gangetic plains of eastern India. Addition of organic residues with inorganic NPK fertilizers significantly increased the nutrient content of the soil. Continuous cropping decreased total C as well as its labile and non-labile fractions. The labile C fractions dominated in the near surface soil layers, but decreased significantly in the deeper layers where the recalcitrant C fraction was significantly dominated down to 0.45 m depth.

References

1. Blanco-Canqui H, Lal R. Crop residue removal impacts on soil productivity and environmental quality. Critical Review of Plant Science. 2009; 28:139-163.
2. Brown S, Lugo AE. The storage and production of organic matter in tropical forests and their role in the global carbon cycle. Biotropica. 1982; 14:161-187.
3. Casico WC. In: Food and Fertilizer Technology Centre for the Asian and Pacific Region, Taiwan, Republic of China. Extension Bulle-tin. 1990, 314-14.
4. Chan KY, Bowman A, Oates A. Oxidizable organic carbon fractions and soil quality changes in an Oxic Paleustalf under different pasture leys. Soil Science 2001; 166:61-67.
5. Elfstrand S, Hedlund K, Martensson A. Soil enzyme activities, microbial community composition and function after 47 years of continuous green manuring. Applied Soil Ecolology. 2007; 35:610-621.
6. Ghosh S, Wilson BR, Mandal B, Ghoshal SK, Growns I. Changes in soil organic carbon pool in three long-term fertility experiments with different cropping systems, inorganic and organic soil amendments in the eastern cereal belt of India. Australian Journal of Soil Research. 2010; 48:413-420.
7. Jarecki MK, Lal R. Crop management for soil carbon sequestration. Critical Review Plant Science. 2003; 22:471-502.
8. Kong AYY, Six J, Bryant DC, Denison RF, Van Kessel C. The relationship between carbon input, aggregation, and soil organic carbon stabilization in sustainable cropping systems. Soil Science Society of American Journal. 2005; 69:1078-1085.
9. Ladha JK. In: Proceedings of Symposium on Sustainable Agriculture: Green manure in rice farming, 25-29, Int. Rice Res. Inst., Philippines, 1987-1988, 165-183.
10. Ladha JK, Dawe D, Pathak H, Padre AT, Yadav RL, Singh B. How extensive are yield declines in long-term rice–wheat experiments in Asia? Field Crops Research. 2003; 81:159-180.
11. Lal R. Soil quality impacts of residue removal for bioethanol production. Soil Tillage Research. 2009; 102:233-241.
12. Lemke RL, Vanden Bygaart AJ, Campbell CA, Lafond GP, Grant B. Crop residue removal and fertilizer N: effects on soil organic carbon in a long-term crop rotation experiment on a Udic Boroll. Agricultural Ecosystem Environment. 2010; 135:42-51.
13. Lu F, Wang X, Han B, Ouyang Z, Duan X, Zheng H *et al*. Soil carbon sequestrations by nitrogen fertilizer application, straw return and no-tillage in China's crop-land. Global Change Biology. 2009; 15:281-305.
14. Majumder B. Soil organic carbon pools and biomass productivity under agro-ecosystems of subtropical India. Ph.D. diss. Jadavpur Univ., Calcutta, 2007.
15. Mandal KG, Misra AK, Hati KM, Bandyopadhyay KK, Ghosh PK, Mohanty M. Rice residue management options and effects on soil properties and crop productivity. Food Agriculture Environment. 2004; 2:224-231.
16. Palaniappan SP. In: Int. Symposium on National Resources Management for sustainable Agriculture, 6-10 February, New Delhi., 1990, 220.
17. Pittelkow CM, Liang X, Linquist BA, van Groenigen KJ, Lee J, Lundy ME *et al*. Productivity limits and potentials of the principles of conservation agriculture. Nature. 2015; 517:365-368
18. Poeplau C, Katterer T, Bolinder MA, Borjesson G, Berti A, Lugato E. Low stabilization of aboveground crop residue carbon in sandy soils of Swedish long-term experiments. Geoderma. 2015; 237-238:246-255.
19. Powlson DS, Glendining MJ, Coleman K, Whitmore AP. Implications for soil properties of removing cereal straw: results from long-term studies. Agronomy Journal. 2011; 103:279-287.
20. Ramachandran Nair, Mohan Kumar. Agroforestry as a strategy for carbon sequestration. Journal of Plant Nutrition and Soil Science. 2009; 172:10-23.
21. Swarup A, Manna MC, Singh GB. Impact of land use and management practices on organic carbon dynamics in soils of India. In R. Lal *et al*. (ed.) Global climate change and tropical ecosystems. Adv. Soil Sci. CRC Press, Boca Raton, FL, 2000, 261-281.
22. Yadav RL, Dwivedi BS, Pandey PS. Rice–wheat cropping system assessment of sustainability under green manuring and chemical fertilizer inputs. Field Crops Research. 2000; 65:15-30.
23. Yadvinder S, Bijay S Timsina J. Crop residue management for nutrient cycling and improving soil productivity in rice-based cropping systems in the tropics. Advances in Agroonomy. 2005; 85:269-407.
24. Zhang S. Effects of conservation tillage on soil aggregation and aggregate binding agents in black soil of Northeast China. Soil Tillage Research. 2012; 124:196-202.