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Soil Organic Carbon Dynamics Under Tropical Garden Land Systems

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ABSTRACT

The organic carbon (OC) status of three continuously cropped permanent manurial experiments, under different cropping systems, over a period of time is discussed in this paper. The Old Permanent Manurial Experiment (OPME) was originally an irrigated experiment started in 1909 and in 1937, converted into a rainfed experiment (at this time the cropping system was converted from two crops per year into a single crop per year). The New Permanent Manurial Experiment (NPME) was started in 1925 and was conducted in an irrigated system with one set of treatments receiving 2 t ha^{-1} of cattle manure since its inception. These two experiments were conducted with different nutrient input management systems of single inorganic nutrients and their combinations. The effect of these treatments on the OC status of the soil was evaluated. Along with these, the changes in the OC status of another irrigated long term fertilization trial which has been conducted since 1972 under the intensive cultivation system with three crops per year were studied. The results obtained in the three experiments showed that there was a build up in the OC status of the soil for the balanced application of N, P, and K combined with an organic manure. Among the inorganic fertilizer treatments, the combined application of all the three major nutrients (N, P and K) resulted in a higher OC status, compared to the application of single nutrients. This may be due to better growth and a higher amount of root residues added after the harvest of each crop, over a period of time. But, in both OPME and NPME, there was a decline in the OC content after seven years and a build up has happened in the last nine years. Under the intensive cropping system of cultivation, the soil organic carbon build up occurred in all the treatments, including the unmanured control, and was the maximum for the combined application of inorganics and organics (100% NPK + Farm Yard Manure (FYM)). The increase in OC is attributed to enhanced root biomass over a period of 30 years.

Keywords: Organic manure, Permanent Manurial Experiments, Soil Organic Carbon.

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INTRODUCTION

A sustainable agro-ecosystem requires the conservation or enhancement of the soil resource, and it is imperative that the organic matter content of the soil is sustained. A decrease in organic matter content is an indication of lower soil quality in most soils. Analysis made by Rozanov *et al*. (1990), showed that 16 percent of original soil carbon stock might have disappeared since agriculture began 10,000 years ago. Also they estimated an overall loss of humus at the rate of 25.3 million t y $^{-1}$ over the past 300 years.

In Indian soils, that are generally low in organic matter, under intensive cropping with imbalanced fertilizer use, soil organic matter (SOM) declined as was shown from the long term fertility experiments (Swarup *et al.* 1998). Though tropical conditions favour organic matter reduction, its level seldom reaches the stage of complete exhaustion. Rather, over cultivated soils tend to attain a steady state, described as the lower equilibrium limit (Buyanovsky and Wagner, 1986).

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At the upper limit of organic matter, the equilibrium content is typical for an individual eco- system. In general, the organic matter content of tropical soils might be reduced to as low as about 30 percent, but most commonly to about 60 percent of that found under indigenous vegetation with an average of ten years of arable farming (Brown *et al.*, 1994). This paper analyses the dynamics of soil organic carbon (SOC) under three different experimental systems and cropping patterns over a period of time conducted at Tamil Nadu Agricultural University, Coimbatore, India. These three experiments are being conducted with an aim of monitoring soil fertility due to continuous intensive cultivation under different farming systems.

MATERIALS AND METHODS

The Old Permanent Manurial Experiment (OPME) has been in place since 1909, in a red sandy soil (Typic Haplustalf). At its inception, the experiment was conducted under irrigated conditions with two crops per year (cereal-cotton). During 1980, the experiment was transformed to a non-irrigated condition, reducing the number of crops per year to one (one cereal crop alone namely, sorghum).

So far, OPME has raised 140 crops. The trial has undergone ten treatments, laid out as non-replicated trials. Until 1979, irrespective of crops, 25-60-75 kg of N, P_2O_5 and K_2O ha^{-1} were applied respectively. In 1980, the plots were subdivided into two, one half receiving the old dose (OD) as done previously and the other half receiving fertilizers based on soil test based fertilization referred as the new dose (ND).

The New Permanent Manurial Experiment (NPME) was started in 1925, in a similar soil (Typic Haplustalf), with the same treatments as in OPME, namely, the control, N, NK, NP, NPK, PK, K, P, cattle manure (CM), and cattle manure residue (CMR- receiving manure in alternate years). It is also a non – replicated experiment. The experimental plots are separated into two. One half receives 2 t ha^{-1} cattle manure as a basal dose irrespective of treatments, due to its low fertility status at the inception of the experiment located on the western side called the western series (WS). The other half does not receive that basal dressing, located on the eastern side, called the eastern series (ES). As with the OPME, the treatment plots of NPME were also subdivided into two during 1988, one half receiving 25-60-75 kg of N, P_2O_5 and K_2O ha^{-1} as OD and the rest receiving soil test - based fertilization. So far, 126 crops have been raised from this site. Both the above experiments are laid out at different locations but in the same type of soil.

A Long Term Fertilizer Experiment was started during 1972 in a mixed black soil. This experiment is laid out with ten treatments in a randomized block design, with four replicates under a cropping system of fingermillet-maize-cowpea (fodder). The treatments were 50, 100, 150%NPK, 100% NPK (hand weeded), 100% NPK+$ZnSO_4$ (for maize), 100%NP, 100%N, 100%NPK + 10 t FYM ha^{-1} (for finger millet), 100%NPK (without sulphur) and control. 100% NPK for the relevant crops are as follows:

Fingermillet	90-45-22.5
Maize	130-65-35
Cowpea (fodder)	25-50-0 kg of N-P_2O_5-K_2O ha^{-1}

This experiment has raised 76 crops under irrigated conditions. In all the three experiments, organic carbon (OC) was determined in the soil samples collected at a depth of 0-15 cm, at irregular time intervals using the method of Walkley and Black (1934).

RESULTS AND DISCUSSION

Organic Carbon Status of OPME

The OC status of this continuously cultivated and fertilized experiment recorded an increase of >150% compared to the first measurement made in 1953. This was over a

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period of 46 years irrespective of treatments except control (Table 1). However, control registered an enhanced OC status from 0.12% during 1953 to 0.25% during 2000. This value has stabilized over a period of twenty years since 1973. Results from an experiment at Pantnagar (Nambiar, 1994) indicated that, after 25 years, SOM was constant in the control during the first 5-7 years. However, during the next 7-8 years, SOM declined sharply to 50 per cent of its original value. In the next 5-7 years there was no decline.

Beyond this point, SOM did not decline and seemed to have stabilized at a lower equilibrium level, as described by Buyanovsky and Wagner (1986). In the present experiment, the initial OC status during 1909 was not known. Assuming the above theory is correct, it would have reduced over a period of 40 years due to continuous cultivation. It has taken up a reverse, in the next 20 years, to build up and reach a state of equilibria during the last 20 years. Unlike the inorganic fertilizer treatments, there was a constant increase in the organic carbon status in plots where cattle manure was applied and the increase over the estimated period was at the maximum in these organic manure applied plots.

Singh *et al.* (1995), reported on the carbon and nitrogen enrichment of different fractions of organic matter as affected by rice and wheat residues since the application of crop residues of a wider C: N ratio is likely to stabilize the N in slowly biodegradable fractions and, in the long term, can improve soil productivity. The application of N, P and K together resulted in a higher OC than the use of single nutrients, due to better growth and higher amounts of root residues added to soils, over the years.

Table 1. Organic carbon status (%) in the Old Permanent Manurial Experiment over a period of years (0-15 cm).

Treatments	Years					
	1953	1957	1974	1976	1979	2000
Control	0.12	0.14	0.18	0.27	0.24	0.25
N	0.11	0.16	0.36	0.16	0.28	0.29
NK	0.13	0.17	0.36	0.30	0.32	0.32
NP	0.13	0.19	0.32	0.27	0.32	0.34
NPK	0.14	0.17	0.33	0.21	0.37	0.40
PK	0.15	0.23	0.35	0.24	0.37	0.37
K	0.11	0.21	0.32	0.25	0.33	0.33
P	0.13	0.26	0.33	0.27	0.33	0.32
Cattle Manure	0.166	0.29	0.22	0.36	0.51	0.54
Cattle Manure Residue	0.14	0.26	0.33	0.27	0.36	0.42

Organic Carbon Status of NPME

Similar to the OPM experiment, there was a build up in the OC status of all the treatment plots over a period of 46 years in the control to 133% under CM treatment. In this experiment, as a result of the basal addition of 2 t CM ha^{-1} to the western series, the OC content of the western series was higher than that of eastern series (Table 2 and 3). Based on estimates made during 1988, the OC content of the NPK plots in the western series was 14% higher than that of the eastern series and with CMR, a difference of 15%. These data clearly indicate that the continuous direct addition of OM through cattle manure application or root biomass added after the harvest of each crop would have contributed to the enhancement of the OC status of the soil. As observed in the NPME

Table 2. Organic carbon status (%) in the New Permanent Manurial Experiment over a period of years (0-15 cm) (Eastern series).

Treatments	Years					
	1952	1967	1980	1989	1992	1998
Control	0.25	0.35	0.51	0.21	0.28	0.28
N	0.24	0.51	0.47	0.54	0.34	0.34
NK	0.25	0.57	0.53	0.42	0.36	0.36
NP	0.23	0.51	0.58	0.57	0.40	0.40
NPK	0.22	0.37	0.56	0.42	0.42	0.42
PK	0.22	0.54	0.54	0.30	0.34	0.34
K	0.21	0.54	0.43	0.36	0.30	0.30
P	0.23	0.47	0.43	0.27	0.32	0.32
Cattle Manure	0.24	0.67	0.68	0.27	0.56	0.56
Cattle Manure Residue	0.24	0.57	0.62	0.48	0.52	0.52

Table 3. Organic carbon status (%) in the New Permanent Manurial Experiment over a period of years (0-15 cm) (Western series).

Treatments	Years					
	1952	1967	1980	1989	1992	1998
Control	0.30	0.52	0.49	0.21	0.32	0.36
N	0.32	0.27	0.55	0.27	0.58	0.40
NK	0.36	0.54	0.51	0.42	0.42	0.40
NP	0.36	0.62	0.55	0.57	0.48	0.42
NPK	0.34	0.24	0.54	0.60	0.51	0.48
PK	0.34	0.29	0.54	0.48	0.52	0.42
K	0.34	0.21	0.62	0.21	0.45	0.40
P	0.35	0.37	0.62	0.36	0.45	0.42
Cattle Manure	0.39	0.29	0.96	0.45	0.66	0.58
Cattle Manure Residue	0.37	0.18	0.67	0.54	0.41	0.60

there was a decline in the OC content after thirty-seven years. Hence, an equilibrium would have established as proposed by Buyanovsky and Wagner (1986). The first no gain-no loss period was due to the transfer of OM rich top soil through erosion from the upper slopes (Gregorich *et al*., 1998).

Organic Carbon Status of LTFE

This experiment is three decades old and the OC estimation was carried out in 1976, four years after its inception in 1972. At that time, the OC content was only 0.3%. A different input management system (Table 4) had an input on the OC status of the soil. With an increase in the levels of fertilization to 150% NPK, the OC content also increased substantially (0.54% to 0.67% during 1999). This could be attributed to the addition of root residues to the soil after each crop. Interestingly, the increase in the OC content in the hand weeded plots was not substantial, even though 100% NPK has been applied.

The addition of $ZnSO_4$ with 100% NPK, did not have any effect on the build up of the OC content of the soil. The elimination of K had a definite effect on OC content, lowering its content by 14% compared to the 100% NPK application. When both P and K were not applied continuously, there was a significant increase in the OC status (67%

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Table 4. Organic carbon status (%) in the Long Term Fertilizer Experiment over a period of years (0-15 cm).

Treatments	Years			
	1976	1985	1992	1999
50% NPK	0.37	0.42	0.43	0.54
100%NPK	0.40	0.43	0.44	0.58
150%NPK	0.42	0.45	0.50	0.67
100%NPK+HW	0.43	0.43	0.47	0.54
100%NPK+ZnSO4	0.38	0.43	0.48	0.56
100%NP	0.39	0.43	0.47	0.52
100%N	0.39	0.42	0.41	0.50
100%NPK+FYM @ 10t ha^{-1}	0.50	0.49	0.53	0.70
100%NPK(-S)	0.44	0.44	0.46	0.52
Control	0.39	0.41	0.34	0.42

increase) when 10 t of FYM ha^{-1} was added with 100% NPK.

This might have been due to the increased biomass of root residues as well as the direct effect of FYM. Brar *et al* (1998) stated that the incorporation of root residues and FYM alone or in combination with green manure significantly increased the soil OC content. Also, 150% of NPK had increased the soil OC status to 0.67%.

CONCLUSION

When compared with the initial soil carbon status in 1972 which had been 0.30% at the inception of the experiment, the intensive cropping since then had resulted in the enhanced OC content, regardless of the nutrient input system, including in the control. The continuous adoption of all the treatments to the high intensive cropping system tended to build up soil organic matter (Brar *et al.*, 1998). The build up was at its maximum in the 100% NPK+FYM applied plots (a 133% increase) followed by 150% NPK (a 123% increase) with reference to the initial level of 0.3%. The increase was also recorded in the control (a 40% increase) and in N alone treatments (a 67% increase).

The increase in OC was attributed to enhanced root biomass over a period of 30 years. Appreciable improvement in soil OC with respect to the initial level was observed at optimal to super optimal (100-150%) NPK doses on almost all the soils (Nambiar, 1994). Decline in SOM with the continuous use of nitrogenous fertilizers has been reported, especially on laterite and black cotton soils by Goswami and Rattan (2000). Such ill effects were eliminated when balanced application of FYM was practiced.

Long term sustenance of soil fertility and higher productivity has been accomplished, provided optimum NPK are supplemented with FYM, since it is due to the manifold beneficial effects where the FYM acts as a store house of nutrients, an improver of soil health, a synergiser of the microbial activity, a soil biomass accumulator and a preserver of bio-diversity. Hence, it is concluded that continuous cultivation (even intensive) with optimum fertilization and organic manuring, would build up soil organic carbon status.

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دینامیک کربن آلی خاک در اراضی تحت سیستم زراعت مستمر در شرایط حاره‌ای

پ. سنسی و ل. دواراجان

چکیده

در این مطالعه وضعیت کربن الی در سه طرح آزمایشی زیر کشت مستمر با مصرف دائم کود الی تحت نظام‌های مختلف کشاورزی در یک دوره زمانی مورد بررسی قرار گرفت. طرح آزمایشی قدیم مربوط به مصرف دائم کود الی (OPME) که در اراضی تحت آبیاری در سال 1909 بمرحله اجرا در آمده و در سال 1937 به یک طرح آزمایشی دیم و از دو به یک محصول زراعی در یک سال تبدیل گردیده بود. در طرح جدید مصرف دائم کود الی (NPME) که از سال 1925 تحت سیستم آبیاری آغاز و هر ساله 2 تن در هکتار کود گاوی مصرف گردید. در هر دو آزمایش از آغاز، مدیریت مصرف عناصر غذایی بصورت مجزا و ترکیبی از آنها بمرحله اجرا درآمد. اثر این تیمارها روی وضعیت کربن الی خاک مورد ارزیابی قرار گرفت. همراه با این تیمارها، در یک آزمایش تغییرات کربن الی خاک از سال 1972 در یک خاک زراعی تحت

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سیستم آبیاری با مصرف طولانی مدت کودهای شیمیایی با کشت متمرکز و سه محصول زراعی در سال مورد مطالعه قرار گرفت. نتایج حاصل از این سه آزمایش مختلف نشان داد که کربن الی در این خاکها در اثر مصرف متعادل N،P و K و مصرف دائم کود حیوانی افزایش یافته است. در بین تیمارهای کودهای شیمیایی، مصرف مخلوط سه عنصر اصلی یعنی N، P و K باعث افزایش بیشتر کربن الی در مقایسه با مصرف تنهایی این عناصر شده است. این موضوع ممکن است بعلت رشد بهتر و افزایش بقایای ریشه پس از برداشت گیاه در یک دوره زمانی باشد. اما در هر دو تیمار OPME و NPME، میزان کربن الی در هفت سال اولیه کاهش ولی در نه سال آخر افزایش یافته است. تحت نظام زراعی متمرکز، افزایش کربن الی در کلیه تیمارها ازجمله تیمار بدون مصرف کود الی و حداکثر آن در تیمار مصرف توام مخلوط کودهای شیمیایی و الی (NPK ٪100 + کود الی حیوانی) مشاهده گردید. این افزایش کربن الی به افزایش وزن بیولوژیک ریشه گیاه در یک دوره 30 ساله نسبت داده می‌شود.

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