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Research Article

LONG-TERM EFFECT OF ORGANIC MANURE AND FERTILIZERS ON SOIL ORGANIC CARBON POOLS UNDER SOYBEAN-SAFFLOWER CROPPING SYSTEM IN VERTISOL

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Abstract: The present investigation was conducted during 2015-2016 under ongoing All India Coordinated Research Project on LTFE with soybean-safflower cropping sequence in Vertisol (Typic Haplusters) that commenced from 2006-2007 at Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. The present investigation was conducted to study the continuous effect of long-term organic manure and fertilizers on soil organic carbon pools under soybean-safflower cropping system. Treatment includes 50% NPK, 100% NPK, 150% NPK, 100% NPK + hand weeding, 100% + $ZnSO_4$ at 25 kg ha^{-1}, 100% NP, 100% N, 100% NPK + FYM at 5 Mg ha^{-1}, only FYM, absolute control, fallow. The experiment was laid out in Randomized Block Design (RBD) with twelve treatments and four replications. Continuous application of organic manure alone or in combination with inorganic fertilizer significantly influenced the soil organic carbon, water soluble carbon, labile carbon, total organic carbon, dehydrogenase activity, carbon management index. The active fraction of soil organic carbon significantly higher in plot receiving 100% NPK + FYM at 5 Mg ha^{-1}. Significantly increase in soil organic carbon (6.89 g kg^{-1}), water soluble carbon (26.93 mg kg^{-1}), and labile carbon (325.50 mg kg^{-1}) with the application of 100% NPK + FYM at 5 Mg ha^{-1}. Integrated use of nutrient sources was significantly increases dehydrogenases activity (50.21 µg g^{-1} soil 24 hr^{-1}), total carbon content (18.76 g kg^{-1}) in treatment receiving 100% NPK + FYM at 5 Mg ha^{-1} and in treatment receiving 150% NPK and only FYM 10 Mg ha^{-1}. As compared to no-fertilizer and no-manure application (control), the carbon management index (CMI) was 2.24 fold higher when organic and inorganic fertilizer applied 100% NPK + FYM at 5 Mg ha^{-1} improvement in the plant stand and increase in organic inputs increase in CMI would serve as better indicator for soil health. Integrated use of FYM with chemical fertilizers or FYM alone exerted significant effect on soil organic carbon pools in soil.

Keywords: Soil organic carbon, Water soluble carbon, Labile carbon, Total organic carbon, Dehydrogenase activity, Carbon management index

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Introduction

Soil organic carbon (SOC) is a basic building block for all life on the earth. It is very important for maintaining soil quantity, productivity, and sustainability soc is a direct source of plant nutrients help in plant growth indirectly influences nutrient availability in soil. Day by day the amount of soil organic carbon in soils of India relatively low ranging from 0.1 to 1% and typically less than 0.5% which affect the soil physical chemical and biological properties [6]. This may be due to high temperature and indiscriminating exploitation of natural resources without considering the carrying capacity and non-judicious use of inputs to fetch higher production and generated serious problem on sustaining agricultural productivity and soil quality. Soil quality had to function within ecosystem boundaries to sustain biological productivity and to maintain environmental quality and promote plant and animal health. To maintain soil health application of manures and fertilizers at optimum rate increases the crop production which in turn results in greater residue inputs leading to enhanced build-up of carbon in soil [13].

The soil organic carbon exists in two pools *viz*., active pool and passive pool. The active pool generally contributes about 10-20% towards total soil organic matter, where as stable or passive pools have 50-60% contribution towards total soil organic matter. Labile C pool is the fraction of SOC with rapid turnover rates and it's oxidation drives the flux of CO_2 from soil to the atmosphere, fuels the soil food web and therefore greatly influences nutrient cycling for maintain soil health and productivity.

The active pool consists of living microbes and their products besides soil organic matter. The active pool has a short turn over and includes soil microbial biomass carbon; water soluble carbohydrates etc. and depend on agro-ecosystem and management. The passive is pool comparatively more stable. Then active pool and slow decomposable having a larger turn over time highly recalcitrant or passive pool is slowly altered by microbial activities and it is not a good indicator of agronomic productivity [11] change in labile pools of soc due to different soil management practices have been studied mainly in cooler and temperate regions of the world but such studies in tropical and subtropical regions of the world are very few where, water stress, high temperature and low biomass are common features. Therefore, present investigation was undertaken to study the effect of continuously application of fertilizers, organic manure on carbon pools under Soybean -Safflower system in Vertisol.

Material and Methods

The present investigation was undertaken during the year 2015-16 on long- term fertilizer experiment which was started in 2006-07 at research farm of Department of Soil Science and Agricultural Chemistry, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India (76º 46'E longitude, 19º16' N latitude and elevation 408m above sea level). The farm is in a semiarid tropic region with hot summer and mild winters, maximum temperature during study years.

The soil of the experimental site was Vertisol particularly montmorillonictic, hyperthermic family Typic Haplustert. The present experiment was conducted during 10th cycle to study effect of different sources of nutrients on SOC pools which includes soil organic carbon, water soluble carbon, labile carbon, total organic carbon, dehydrogenase activity, carbon pool index, carbon lability index, carbon management index. The present experiment was framed in randomized block design withy twelve treatments and four replications in Soybean-Safflower cropping sequence. The treatment comprises *viz*., T1-50% NPK, T2-100% NPK, T3-150%NPK, T4-100% NPK + hand weeding, T5-100% NPK + ZOSO4 at 25 Kg ha^{-1} T6-100% NP, T7- 100% N, T8-100% NPK +FYM at 5 Mg ha^{-1}, T9 -100% NPK –Sulphur, T10 – Only FYM at 10 Mg ha^{-1},T11-Absolute control and T12 - Fallow. The crop Soybean (cv.JS-335) and Safflowers (*cv*. PBNS-12) more raised during kharif (rainy) and rabi (post rainy) respectively with recommended package of practices. Soybean and safflower crops were sown with 45 × 5 cm and 45 × 10 cm spacing between rows and plants respectively. The 100% NPK was 30:60:30 kg ha^{-1} for soybean and 60:40:00 kg ha^{-1} for safflower respectively. The fertilizers used were urea, single super phosphate (SSP) and muriate of potash. FYM was applied 15 days before sowing only for kharif crop and NPK applied were applied as per treatments, in treatment T9 instated of single super phosphate (SSP) diammonium phosphate was used to avoid sulphur application. In T4 treatment only two hand weeding were undertaken for weed control no application of herbicides. Inorganic micronutrients were applied through chemical fertilizers ($ZnSO_4.5H_2O$). Soil sample were collected by from surface (0-15, 15-30 cm depth in keep in well labelled polythene bags and brought to the laboratory. A representative part of each sample was air dried and sieved through a 2 mm sieve. The organic carbon in soils was measured as by Walkley and Black, (1934). Labile carbon (LC) determined by easily oxidizable carbon according to degrees of lability in which H_2SO_4 concentration varies at the stable concentration of $K_2Cr_2O_7$ Chan, *et al*., (2001). Water soluble carbon (WSC) was determined using the method as described by [7]. Ten grams soil was taken in centrifuge tube and 20 ml of distilled water was added. The tubes were centrifuged for 1 h at 5000 rpm and the supernatant aliquot was filtered 10 ml of filtrate should be taken followed by 2 ml of 0.1 N $K_2Cr_2O_7$ subsequently sulphuric acid and 5 ml of 88% H_3PO_4 orthophosphoric acid should be added and keep on water bath for 1 hour samples were titrated by using 0.01N ferrous ammonium sulphate (FAS) using 1 ml of diphenylamine indicator. Dehydrogenase enzyme activity in soil Klein, *et al*., (1971) was determined by triphenyl formazan (TPF) produced by the reduction of 2,3,5-triphenyl tetrazolium chloride (TTC).

Estimation of carbon management index

The more a soil has been depleted of carbon the more difficult it is to rehabilitate. The carbon pool index (CPI) takes it in account. The loss of labile C is of greater consequence than the loss of non-labile of C which is terms of carbon lability index (CPI). Various carbon indices were worked out as follows [6].

$$CPI = \frac{Total\ organic\ \ carbon\ in\ sample}{Total\ organic\ carbon\ in\ unfertilized\ and\ unmanured\ plot}$$

$$CLI = \frac{Lability\ in\ land\ use}{Lability\ in\ unfertilized\ and\ unmanured\ plot}$$

Where, lability is the ratio of easily oxidized organic carbon to unoxidized organic carbon.

Statistical analysis

The experimental data was subjected to analysis of variances (ANOVA) and treatment means were tested at P = 0.05 using randomized block design (RBD) as described by [9].

Results and Discussions

Soil organic carbon

The value of soil organic carbon varied from 5.49 g kg^{-1} in control to 6.89 g kg^{-1} in FYM and inorganic fertilizer treated plot. Continuous application of FYM alone or in combination with inorganic fertilizer results in higher organic carbon content as compared to in inorganic fertilizer application after harvest of soybean-safflower. Maximum accumulation of soil organic carbon observed in treatment receiving 100 % NPK in combination with FYM at 5 Mg ha^{-1} (6.89 g kg^{-1}) followed by treatment only FYM at 10 Mg ha^{-1} (6.61 g kg^{-1}), treatment receiving 150 % NPK (9 g kg^{-1}) whereas lowest soil organic carbon content in absolute control (5.49 g kg^{-1}). This could be attributed to direct incorporation of organic matter, better root growth and more addition of plant residues. Application of nitrogenous fertilizers alone recorded lowest organic carbon (5.60 g kg^{-1}) which may be attributed to poor crop growth and poor plant residues in absent of phosphorus and lowering pH [5]. Further, soil organic carbon content also increased significantly with the application of 100% NPK, 100 % NPK + Zn, 100% NPK + hand weeding, 100% NPK, 1000% NPK-S over control. This shows that use of fertilizer alone also helps in increase in organic carbon content of soil. The reason attributed is higher contribution of biomass to the soil in the form of larger root biomass, crop stubbles and residues. The treatments of inorganic fertilizer application also showed significant increase in organic carbon build up. Increase in organic carbon content could be ascribed due to contribution from annual use of organic manure at FYM 5 Mg ha^{-1} along with 100% NPK during period of experimentation and also due to increased level of fertilizer application which might have helped in increasing the organic carbon content in soil and also due to increased contribution from dry leave, roots, stubbles, and another crops biomass [3].

Water soluble carbon

Water soluble carbon is active pool, labile and mobile form of soil organic carbon and immediate organic substrate for micro-organisms. It is it is easily degraded by micro organisms and that serve as energy source and sink for mineral nutrients and organic substrate in a short-term act as catalyst for conversion of plant nutrients from stable organic forms and influence crop productivity and nutrient cycling. The value of water soluble carbon varied from 12.75 mg kg^{-1} to 26.93 mg kg^{-1}. Results indicated that there was significant build up of water soluble carbon in treatment receiving 100% NPK along with 5 Mg ha^{-1}(26.93 mg kg^{-1}) significantly superior over other treatments. Lowest water soluble carbon observed in control (12.75 mg kg^{-1}). Balanced fertilizer dose 100% NPK either alone or in combination with FYM resulted in significant increase in water soluble carbon. The FYM sustain higher amount of water soluble carbon, whereas increasing graded doses of chemical fertilizers increased their content in soil. The higher water-soluble carbon content in surface layer might be due to addition of plant residues and microbial activity. The increase in water soluble carbon content might be due to application of nitrogen fertilizer on fresh organic material in soil which stimulates the microbial activity helping in decomposing of soil organic matter with rapid release of water soluble carbon fraction [1].

Labile carbon

Labile pool of carbon is the fraction of soil organic carbon that has the most rapid turnover rates and therefore, it's oxidation drives the flux of carbon dioxide from soil to atmosphere. Also, the labile carbon pool is one which is readily decomposable, easily oxidizable and susceptible to microbial attack and sensitive to management practices induced changes in soil organic carbon. The pool is very important as it fill the soil food web and greatly influences the nutrient cycling for maintaining the quality of soil and it's productivity. The labile pool of carbon varies from 209 mg kg^{-1} to 326 mg kg^{-1}.

The labile pool of carbon was significantly highest observed with the application of 100 % NPK in combination with 5 Mg ha^{-1} FYM (325.50 mg kg^{-1}) and at par with only FYM at 10 Mg ha^{-1}.(315.00 mg kg^{-1}). The treatment of inorganic fertilizer application also showed significant increase in labile carbon over control. This could be attributed to increase in labile carbon content due to direct incorporation of organic matter better root growth and plant residue addition after harvest of crops [4, 10]

Total organic carbon

The total organic carbon content of soil influenced by long-term integrated nutrient management and relevant data present in [Table-2]. Total organic carbon content varies from 12.94 g kg^{-1} to 18.76 g kg^{-1}.

Table-1 Long-term effect of organic manuring and inorganic fertilization on soil carbon pools under soybean-safflower sequence

Tr. No.	Treatment details	Soil Organic Carbon (g kg^{-1})	Water Soluble Carbon (mg kg^{-1})	Labile carbon (mg kg^{-1})
T_1	50%NPK	5.93	18.34	218
T_2	100%NPK	6.21	20.77	234
T_3	150%NPK	6.54	24.34	279
T_4	100%NPK+ HW	6.39	20.59	215
T_5	100%NPK+Zn	6.46	21.75	239
T_6	100%NP	5.83	17.80	231
T_7	100%N	5.60	16.73	216
T_8	100%NPK+FYM	6.89	26.93	326
T_9	100%NPK-S	5.67	19.00	231
T_{10}	FYM	6.61	25.39	315
T_{11}	Control	5.49	12.72	209
T_{12}	Fallow	5.65	16.25	217
CD (*P=0.05*)		0.40	2.63	18.16

Table-2 Dehydrogenase activity, TOC and carbon indices influenced by organic manuring and inorganic fertilization under soybean-safflower sequence

Tr. No.	Treatment details	Dehydrogenase (µg g^{-1} soil 24 hr^{-1})	TOC (g kg^{-1})	Carbon Pool Index (CPI)	Carbon Lability Index (CLI)	Carbon Management Index (CMI)
T_1	50%NPK	33.74	14.89	1.15	1.04	1.19
T_2	100%NPK	35.73	15.46	1.19	1.12	1.33
T_3	150%NPK	47.08	16.87	1.30	1.34	1.74
T_4	100%NPK+ HW	36.39	15.84	1.22	1.03	1.25
T_5	100%NPK+Zn	37.99	16.39	1.26	1.14	1.43
T_6	100%NP	34.59	14.69	1.13	1.11	1.25
T_7	100%N	32.90	13.92	1.07	1.02	1.09
T_8	100%NPK+FYM	50.21	18.76	1.44	1.56	2.24
T_9	100%NPK-S	39.34	14.93	1.15	1.12	1.28
T_{10}	FYM	45.59	18.41	1.42	1.46	2.07
T_{11}	Control	30.00	12.94	1.00	1.00	1.00
T_{12}	Fallow	31.86	13.85	1.07	1.04	1.11
	CD at 5%	3.07	1.89			

TOC observed highest in treatment receiving 100 % NPK combination with 5 Mg ha^{-1} and at par with T10 (18.41 g kg^{-1}) only FYM at 10 Mg ha^{-1}, T3 150% NPK (16.87 g kg^{-1}), T5 100% NPK + Zn (16.39 g kg^{-1}). The conjoint use of chemical fertilizers with FYM found beneficial for maintain high TOC compared to use of chemical fertilizers only. Increase in carbon content due to use of organic and inorganic fertilizers which have produced higher biomass and that in turn improved organic carbon content [12, 14]

Dehydrogenase activity

The data on dehydrogenase activity is soil after harvest of soybean-safflower system indicated that conjoint application of inorganic fertilizer and organic manure *i.e.*, 100% NPK + FYM at 5 Mg ha^{-1} significantly increased dehydrogenase enzyme activity in soil (50.21 µg g^{-1} soil 24 hr^{-1}) at par with T3 150 % NPK (47.08 µg g^{-1} soil 24 hr^{-1}) and T10 only FYM 10 Mg ha^{-1} (45.59 µg g^{-1} soil 24 hr^{-1}).But enzyme activity was drastically reduced in absolute control (30.90 µg g^{-1} soil 24 hr^{-1}) and improved slightly with increasing fertilizer dose. The greater enzyme activity reflected due to increased organic carbon content in soil. The activity of enzyme can be attributed to microbial origin developed during decomposing of organics which act as good source of carbon and energy to heterotrophs by which their population increased in enzyme activities. The enzymes activity was significantly lower in all treatment of imbalanced fertilization (nitrogen alone and 50% NPK) Significantly positive correlation between soil organic carbon and dehydrogenase activity. The stronger effect of FYM on dehydrogenase activity might be due to more easy decomposition of organic matter and due to the increase in microbial growth with addition of carbon substrate [8].

Carbon pool index (CPI), carbon lability index (CLI) and carbon management index

The loss of carbon from a soil with a large carbon pool is of less consequence than the loss of same amount of carbon from a soil already depleted of carbon or which started with smaller total carbon pool. Similarly, the more difficult it is to rehabilitate. To account this carbon pool index (CPI) was calculated. The CPI varied between 1.00 to 1.44 Maximum Carbon pool index was observed in T8 treatment receiving 100% NPK + FYM at 5 Mg ha^{-1} (1.44) significant increase in CPI with application of organic and inorganic fertilizer. The lability of carbon is a ratio of labile carbon to non-labile in various treatments. The CLI varied between 1.00 to 1.56 among various treatments. The highest CLI was recorded under treatment receiving 100% NPK + FYM at 5 Mg ha^{-1}.

The carbon management index, a cumulative index that compare the changes that occur in total and labile carbon. It varied between 1.00 to 2.24 among various treatments. The CMI indicate that treatment T8 100% NPK + FYM at 5 Mg ha^{-1} 2.24 fold better than no fertilizer no manure application. From this table improvement in the plant stand and increase in organic inputs increase in CMI would serve as better indicator for soil health in terms of carbon management among three indices.

Conclusions

It can be concluded from the above findings that continuous cropping with soybean-safflower system over 10th cycle, conjoint use of organic manure along with 100% NPK significantly superior over rest of the treatment with respect to soil organic carbon, water soluble carbon, labile carbon, total carbon content and dehydrogenases activity in soil and increases soil fertility.

Application of research

Integrated application of organic and inorganic fertilizer increases soil organic carbon, carbon pool index, carbon lability index and carbon management index over control and helps to improve soil health.

Research Category: Soil Science

Abbreviations:

FYM: farm yard manure
RBD: randomized block design
CPI: Carbon pool index
CLI: Carbon lability index

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