Carbon credit in soil under a long-term fertilizer experiment on mulberry

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Abstract: The study aims at the enumeration of soil organic carbon (SOC) and soil inorganic carbon (SIC) stocks under a long-term fertilizer experiment (LTFE) on mulberry (*Morus alba* L., var. S-1635), continuing for more than five years at Central Sericultural Research and Training Institute, Berhampore (West Bengal), India. Under the experimentation, combinations of organic, inorganic and biological sources of nutrient inputs have been used along with sole inorganic nutrient inputs and control with no nutrient inputs in the mulberry plantation of 60 cm × 60 cm and 90 cm × 90 cm spacing. SOC stock has been improved due to application of organic as well as inorganic combination of nutrients resources and also organic, inorganic as well as biological combination of nutrients resources over sole chemical fertilizers as well as treatment without any nutrient input. But, SIC stock has furnished its higher titre in sole chemical fertilizers as well as treatment without any nutrient input in comparison to others. The inverse relationship between the two indicates an increase of one at the expense of the other. SOC stock has, in turn, imparted significant positive effect on the yield as well as nutrient-uptake attributes of mulberry (var. S-1635) and soil fertility, but, SIC stock has imparted reverse effect on the same. Thus, mulberry nutrient management systems comprising of inorganic, organic as well as biological combinations of nutrients resources are capable of earning such a carbon credit in soil that can exert positive influence on mulberry nutrition and soil fertility under continuous cropping.

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1. Introduction:

Total carbon in soil is defined as the sum of both the organic and inorganic carbon, but these two forms are reported to affect soil attributes and plant productivity differently (Singh *et al*., 2005). Soil organic carbon (SOC) is principally created through assimilation of carbon dioxide by vegetation for manufacturing of living tissue of the latter and subsequent incorporation of biomass into the soil. This is one of the important biological processes of carbon sequestration and the same has huge effect on the Global carbon cycle. On the other hand, soil inorganic carbon (SIC) is formed through the process of ‘carbon sequestration by mineral carbonation’. The process involves reacting atmospheric carbon dioxide with abundantly available metal oxides in soil to form stable carbonates and these reactions occur naturally through weathering of rocks over geologic time periods. The soil is the largest terrestrial pool of organic carbon with global estimates ranging from 1115 to 2200 Pg (Batjes, 1992) while reserves of inorganic carbon have been estimated to be 780-930 Pg (Schlesinger, 1982). The estimates of SOC stock (SOCS) and SIC stock (SICS) in Indian soils are reported as 9.55 Pg and 4.14 Pg, respectively. An assessment of SOCS and SICS and their densities with reference to sampling time constitutes a baseline database for studying influence of management on carbon dynamics.

Mulberry, being an important leaf crop of India occupies an area of 1.81 lakh hectares (Anonymous, 2012). The bio sequestration of carbon in sericulture via SOC enhancement would induce dissolution of native calcium carbonate and its leaching (Bhattacharya *et al*., 2009), resulting in SIC sequestration. However, no specific information is available on such synergy between SOC and SIC sequestration in mulberry farming. Mulberry nutrition management is already standardized in terms of different combinations of nutrient-inputs of organic, inorganic and biological origin (Kar *et al*, 1997; Setua, 2006). The enhancement of SOCS due to application of organic and biological inputs in mulberry farming has also been reported recently (Kar *et al*., 2012). But, information on the change of inorganic carbon stock in soil due to intervention of different sources of nutrient inputs is lacking. Therefore, the present study has been undertaken to investigate the balance of SOC and SIC reserve under a LTFE on mulberry (var. S-1635) comprising nutrient inputs of varying origin. It has also been attempted to relate SOCS and SICS with yield as well as nutrient-uptake of mulberry and soil fertility.

2. Materials and Methods:

The LTFE for the present study has completed 25 crop cycles (5 cycles $year^{-1}$) in a factorial RBD at Central Sericulture Research and Training Institute Berhampore, West Bengal, India with five combinations of nutrient inputs along with control, with three replications using the sapling of S-1635 mulberry variety with two spacing of 60 cm × 60 cm and 90 cm × 90 cm. The plantation has been maintained by following the recommended package of practices under irrigated condition. The treatment combinations are as follows:

Treatment	Combination of nutrient-inputs (kg ha^{-1} $year^{-1}$)
T1	No nutrient
T2	$N_{336}P_{180}K_{112}$
T3	$N_{336}P_{180}K_{112}$ + FYM_{20mt}
T4	$N_{168}P_{180}K_{112}$ + FYM_{20mt} + N-biofertilizer$_{20}$
T5	$N_{168}P_{90}K_{112}$ + FYM_{20mt} + N-biofertilizer$_{20}$ + AMF
T6	$N_{336}P_{180}K_{112}$ + VC_{10mt}

Here, FYM stands for farmyard manure applied @ 20 mt ha^{-1} $year^{-1}$, AMF stands for arbuscular mycorrhizal fungi applied @75 kg ha^{-1} once in four years and VC stands for vermicompost applied @10 mt ha^{-1} $year^{-1}$. While NPK- fertilizers and N-biofertilizer have been applied in five equal splits corresponding to five crops of a year, FYM and VC have been applied in single split per year.

For quantification of SOCS and SICS after completion of five years of experimentation, soil samples collected down the depth of 30 cm under each treatment were analyzed for estimation of bulk density (BD), organic carbon (OC) and inorganic carbon (IC) content. BD was determined by employing the 'core-cutter' method (Blake and Hartage, 1986), OC was estimated following the method of rapid chromic acid oxidation (Black, 1965) and IC was estimated by calcium carbonate equivalent method (Jackson, 1973). The analytical values of OC and IC were converted to total soil OC and IC, respectively by standard factors.

Ultimately, SOCS and SICS under different treatment have been worked out with the help of following equation:

$$S = \rho . C. d……….. (1)$$

Where, S is the SOCS/ SICS (Mg ha^{-1}), ρ is the BD (Mg/ ha-m^{-1}), C is the total SOC/ SIC content (kg Mg^{-1}) and d is the depth (m) of soil.

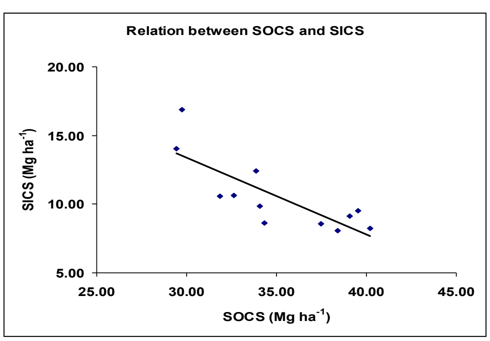
Leaf and shoot yield of the mulberry, var. S-1635 have been recorded crop wise and pooled on annual basis. NPK uptake by mulberry have been estimated by employing the standard procedures of Jackson (1973) while available NPK contents of soil have also been determined by following the respective standard procedure. Regression analysis has further been done to ascertain the impact of SOCS and SICS on yield as well as NPK-uptake of mulberry, var. S-1635 and also NPK-availability in soil.

3. Results and Discussion

Bulk density and carbon stocks in soil under LTFE on mulberry

Figure I furnishes the variation of BD of mulberry (var. S-1635) growing soil under different combination of nutrient-inputs for five years, which revealed substantial improvement in BD due to application of FYM and VC over sole chemical fertilizer as well as treatment without any nutrient input. However, the trend of result is similar in both the spacing, but spacing itself has not imparted any significant effect. Application of organics has improved the BD of the soil under experimentation and the same has been approaching towards the optimum with special reference to mulberry cultivation (Bongale and Siddalingaswamy, 1996; Kar *et al*., 2008). Organic manures on decomposition have produced humic acids and the latter has facilitated formation and stabilization of soil aggregates to improve BD through ionic interaction with soil particles (Sanyal and Majumder, 2009).

SOCS and SICS are also found varying substantially under different treatments comprising varying combinations of nutrient inputs (Figures II and III). Improvement in the status of SOCS due to application of organic manures and fertilizers is quite likely and can be explained in terms of source-sink relation. However, leaf fall from the mulberry plant is also likely to affect the total SOCS and the same is reflected in the treatments comprising sole chemical fertilizer as well as treatment without any nutrient input (Kar *et al*., 2012). But, variation of SICS under different treatments comprising varying combinations of nutrient inputs registers almost reverse trend than that of SOCS furnishing higher titre of SIC in sole chemical fertilizer as well as treatment without any nutrient input. Induced dissolution of SIC in the presence of organics may be the root cause for such finding (Bhattacharya *et al*., 2009). The reverse trend of SICS under different treatments may be correlated with the negative inter-relationship between the two forms of carbon, which indicates an increase of one at the expense of the other (Singh *et al*., 2005). A schematic representation of the same is furnished below:

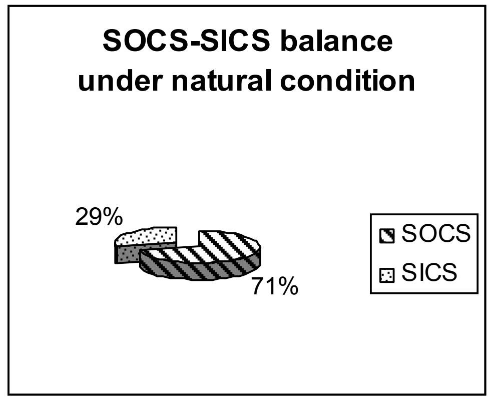


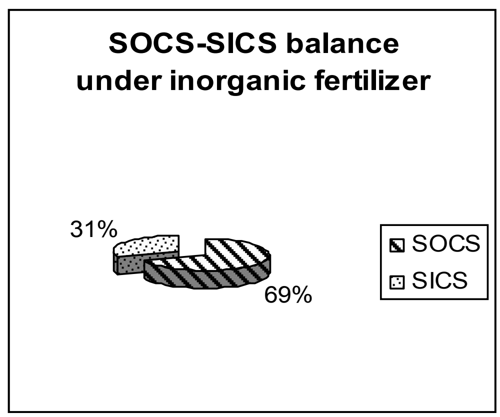
The regression equation relating SICS (y) with SOCS (x), $y = 30.916 - 0.581x$ ($R^2 = 0.682^{**}$), further confirms the above justification. It is interesting to note that unlike BD and SOCS, SICS has been affected significantly by plant-spacing reckoning higher values under wider spacing in most of the treatments. The finding may explained in terms of lesser vegetative cover under wider spacing coupled with the recurrent exposure of calcareous sub horizon of such soil under LTFE (Kar *et al*., 1997).

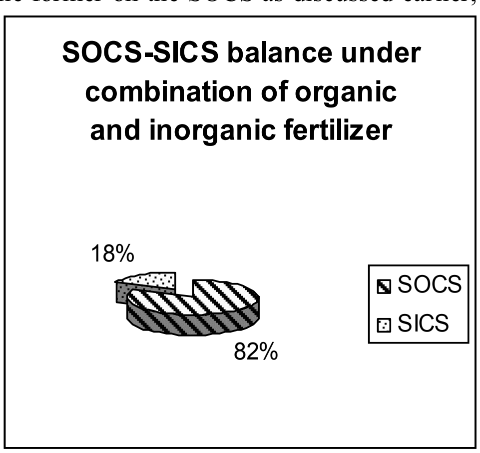
Impact of carbon stocks on soil fertility and mulberry attributes

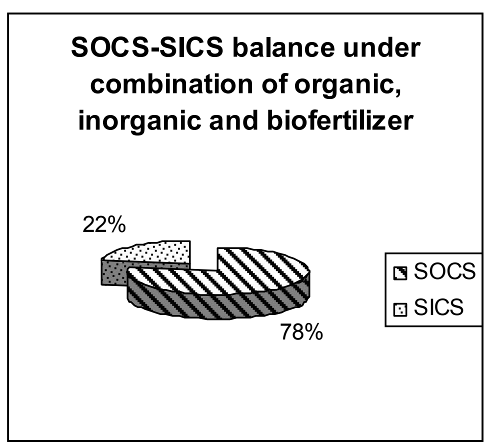
Table 1 furnishes the effect of SOCS as well as SICS on yield, nutrient-uptake attributes of mulberry and soil fertility in terms of regression equations. Most of the attributes studied are significantly and positively affected by the SOCS but negatively correlated with the SICS as evinced by positive and negative partial regression coefficient for SOCS and SICS, respectively. Thus, the treatment comprising of organic, inorganic as well as biological sources of nutrient inputs have not only improved physical property of soil and enhanced the SOCS but also, in turn, promoted the performance of mulberry in terms of its productivity as well as nutrient-uptake attributes and in addition enriched the soil fertility too. The supplementary and complementary use of organic manures, inorganic fertilizers and bio-fertilizers has augmented the efficiency of the applied substances to maintain a high level of soil fertility under organic ambience (Thakuria *et al.,* 1991*),* which in turn, enhanced nutrients mobilization into mulberry plant resulting in the improvement of its leaf as well as shoot productivity. Similar reports are also quite available in agriculture crops (Hati *et al.,* 2008; Swarup and Singh, 2009) relating soil organic carbon reserve and productivity of crops. The negative impact of SICS on mulberry yield and nutrient-uptake attributes may be explained in terms of retarding effect of the former on the SOCS as discussed earlier, which in turn, impaired the role of organic ambience in soil towards amplification of its productivity.

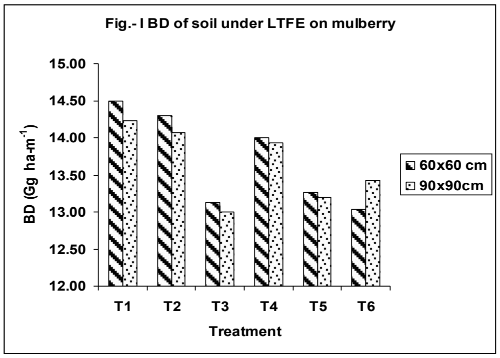
The finding of the study as discussed highlighted the use of balanced fertilization in mulberry under continuous cropping for augmentation of soil as well as mulberry productivity. The plausible reason for the same is earning of a carbon credit in terms of higher proportion of SOCS in comparison to SICS due to continuous application of a combination of inorganic, organic and/ or bio-fertilizer as depicted below:



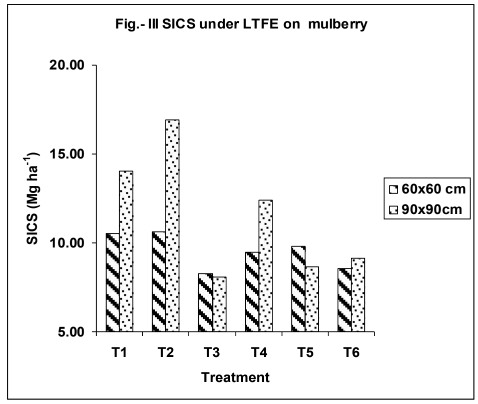








CD* $_{Nutrient}$ – 0.73 CD*$_{Nutrient}$ – 4.5
CD*$_{Spacing}$ - NS



CD*$_{Nutrient}$ – 2.00; CD*$_{Spacing}$ – 1.15

Table 1. Regression equations relating SOCS and SICS with soil fertility, mulberry (var. S-1635) yield as well as nutrient-uptake attributes.

Regression analysis	Regression equation	Multiple R
Relating SOCS (x_1) and SICS (x_2) with leaf yield (y)	$y = 28.45 + 0.27\ x_1 - 0.99\ x_2$	0.41*
Relating SOCS (x_1) and SICS (x_2) with shoot yield (y)	$y = 15.60 + 0.24\ x_1 - 0.65\ x_2$	0.42*
Relating SOCS (x_1) and SICS (x_2) with N uptake (y)	$y = 234.54 + 3.19\ x_1 - 9.35\ x_2$	0.42*
Relating SOCS (x_1) and SICS (x_2) with P uptake (y)	$y = 34.89 + 0.43\ x_1 - 1.46\ x_2$	0.53**
Relating SOCS (x_1) and SICS (x_2) with K uptake (y)	$y = 177.62 + 2.57\ x_1 - 7.61\ x_2$	0.49**
Relating SOCS (x_1) and SICS (x_2) with soil available N (y)	$y = 201.47 + 1.03\ x_1 - 1.85\ x_2$	0.32
Relating SOCS (x_1) and SICS (x_2) with soil available P (y)	$y = 17.87 + 0.45\ x_1 - 0.83\ x_2$	0.59**
Relating SOCS (x_1) and SICS (x_2) with soil available K (y)	$y = 327.14 + 1.74\ x_1 - 5.44\ x_2$	0.57**

Incessant application of such balanced combination of fertilizer elements over the years has developed an organic ambience in soil through the formation of stable compounds of carbon (Kar *et al*., 1995) and, thus, reduced the chances of carbon reversion from soil to atmosphere. The reduced reversion of carbon from soil to atmosphere is also related to the reduction of SICS under balanced fertilization in mulberry as mentioned and the same has indeed a meaningful bearing with the recent agenda of Global warming.

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