# Carbon Sequestration Potential of Fodder Maize (*Zea Mays L.*) Influenced by Manure Treatment Techniques

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***Abstract*—** Increasing carbon sequestration in agricultural soils and making soil a net sink for atmospheric carbon can be achieved by adoption of best manure management practices. The present study was undertaken to evaluate the influence of different manure treatment methods on carbon sequestration potential of popular fodder maize. The significantly higher cumulative carbon sequestration potential was recorded in improved (T6:4.06 t/ha), followed by enriched (T5:4.01t/ha) and vermicompost (T2:3.47 t/ha) treatments than farmer's (T4:3.06t/ha), inorganic (T3:2.64t/ha) and control (T1:1.39t/ha) treatment groups at 60$^{th}$ day. The treatments T6, T5, T3 and T2 recorded higher green fodder yield than the other treatment groups. T6 (4.15 t/ha), T5 (4.11 t/ha) and T2 (4.06 t/ha) treatments had significantly ($P<0.01$) higher carbon sequestration potential (CSP) than other treatments. It was concluded that application of improved, enriched and vermicompost manure sequestered higher carbon from the atmosphere than other treatments, implying the benefit for reducing the impact of carbon, one of the potential green house gases

***Keywords*—** carbon sequestration, fodder maize, manure treatment.

## I. Introduction

INDIA is a nation which possesses a coveted position as a sub-continent in the world's geographical map. India is an agricultural nation, supported by a major share of livestock population in the world with rich diversity in germplasm. Though, livestock is the backbone of agriculture, the significant environmental issues related to livestock waste disposal is still a matter of concern in India. Approximately, 50 per cent of the total dung is productively processed and remaining is applied to the agricultural farm and fields, dumped or washed away. Techniques to treat manure for improving its quality for better disposal mechanisms are not widely taken up for research and as a result, disposal of manure is poorly addressed. Similarly, dung and other dairy farm waste presently stored in the open, create compounding problems. Agriculture and livestock accounts for 50 per cent of total methane emission (5 million tons per year), while methane and nitrous oxide accounts for 23 and 22 per cent of India's current GHG emission [1]. GHG emission is considered as one of the major factors causing global warming and is a global concern particularly among countries like India where livestock population constitutes is more. Maintenance of high concentration of soil organic carbon (SOC) has profound effect on soil quality. It encourages aggregation, increases water retention, nutrient supply and microbial activity by improving soil fertility and productivity [2], thereby ensuring the long-term sustainability of an agro ecosystem. Soil can also be a sink for atmospheric carbon dioxide ($CO_2$) and increased sequestration of carbon in the agricultural soils has the potential to mitigate the global increase in atmospheric greenhouse gases [3]. Increasing carbon sequestration in agricultural soils and making soil a net sink for atmospheric carbon can be achieved by adoption of best management practices, for example conservation tillage, application of fertilizers, organic amendments, crop rotation and improved residue management [4]. Among these practices, the benefits of balanced application of mineral fertilizers and manure in maintaining and increasing levels of SOC in agricultural soil [5] are of foremost importance. There is an increasing awareness among environmental scientists that the effective method of mitigating increasing carbon load is through the enhancement of soil carbon (or organic matter) accretion [6]. Hence, sequestration of the excess carbon from the atmosphere necessitates a sustainable approach to capture excess $Co_2$ in an integrated manner that satisfies the biogeochemical and ecosystem norms. At present, the capacity of the soil to sequester carbon globally is estimated to be 0.4 – 1.2 Gt C/yr [7]. Hence, the present study was conducted for evaluating fodder maize for its carbon sequestration potential to offset increase of carbon concentrations in the atmosphere, while growing maize in different manure treatment methods.

## II. Materials And Methods

Field experiments were conducted to study the effect of different manure treatment techniques on the carbon sequestration potential of the annual fodder crop fodder maize (*Zea mays L.*). The study was carried out in a private dairy farm at Mandapam village, Kancheepuram district, located at

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70 km south of Chennai city at an altitude of 35.1 m above MSL, with latitude of 12°.41’ 08.26’’ N and longitude of 79° 55’ 27.39’’ E. The climate was warm and humid, classified as “tropical maritime monsoon” type. Based on the past five years metereological record it was found that the maximum temperature ranged from 28.5° C to 39.1° C and the minimum temperature from 21.1°C to 26.5°C. The average rainfall was 1098.69 mm. The number of rainy days in a year varied from 47 to 60 in the past five years and maximum rainfall occurred during North East Monsoon Season. The study was carried out during Mar 2012 to May 2012. A composite soil sample was collected at a depth of 0-15 cm in the entire experimental farm prior to the study and analysed for the physico-chemical properties. The study area had a pH of 7.3, 0.59 Electrical conductivity, 0.33% Organic Carbon, Nitrogen of 87.22 kg/acre, Phosphorus of 14.24 kg/acre and 108.97 kg/acre Potassium.

The crop studied was fodder maize *(var. African Tall)* in randomized block design. Treatment imposed were T1, as control-without farmyard manure, T2 as vermicompost with 5.95 t/ha, T3 as inorganic fertilizer (Recommended dose of NPK) with Urea: 130 kg/ha, Super Phosphate: 250 (kg/ha) Potash: 33 kg/ha, T4 as farmyard manure –farmers practice with 6.73 t/ha, T5 as enriched farmyard manure (Composted enriched with rock phosphate in manure pit) with 6.15 t/ha, T6 was improved farmyard manure (dung, feed refusal and urine mixed properly composted in the covered manure pit and turned at fortnight interval) with 6.45 t/ha. Quantity of manure application was calculated based on nitrogen content, equating to N requirement of the plant. The main plot was allotted to fodder maize and sub-plots were allocated for the different manure treatments. The size of each plot was 4 x 6 m and standard agronomical practices were followed for cultivation. The land was ploughed twice by a tractor with chisel ploughing followed by harrowing. The field was brought to fine tilt, leveled with a wooden plank and laid out in to the plots as per the plan lay out. Manure treated by different methods was applied to the plots earmarked for the particular treatment and mixed well in the soil. Ridges and furrows were created with crop spacing based on the fodder crop selected for the study. Fodder maize was planted at 30 x 15 cm intervals on either side of the ridges. The necessary after care operations such as hand weeding was done as per the requirement. Also plant protection measures were taken to control pest and disease. Irrigation was carried out immediately after sowing ($0^{th}$ day), on $3^{rd}$ day and thereafter once in 7 days for annual fodder crops. Harvesting was carried out at 60 days for annual fodder crops at full maturity stage. The annual crops were cut close to the ground. Initial representative soil samples ($0^{th}$ day) were collected from all the experimental plots and also during the crop growth at a depth of 15 cm. Subsequent sampling was done $30^{th}$ and $60^{th}$ day. The soil samples were dried in oven (at 80°C) overnight, ground in wooden mortar and pestle, seived to pass through <2 mm mesh and subjected to analysis. The soil samples collected were analysed for total organic carbon and total nitrogen by using Analyticjena multi N/C 2100S carbon analyzer, with furnace temperature of 950°C, NDIR detector and oxygen as supportive gas.

The carbon sequestration was calculated in terms of increase in carbon stock in soil.

MSOC = SOC x BD x T

Where

MSOC-Mass of Soil Organic Carbon (t/h)

SOC-Soil organic carbon (%)

BD-Bulk Density

T-Thickness of surface layer (cm)

The Soil bulk density was calculated using the following equation [8].

BD (Mg $m^{-3}$) = 1.51-0.113 x SOC (%)

Where BD = Bulk density of the soil and

SOC is Soil organic carbon content (%)

The carbon sequestration potential of the different manure treatments over control was calculated using the following equation [9].

CSP_T2 = MSOC_T2 – MSOC_T1

CSP_T3 = MSOC_T3 – MSOC_T1

CSP_T4 = MSOC_T4 – MSOC_T1

CSP_T5 = MSOC_T5 – MSOC_T1

CSP_T6 = MSOC_T6 – MSOC_T1

Where CSP -Carbon Sequestration potential

MSOC-Mass Soil Organic Carbon

T1-Control, T2-Vermicompost, T3-Inorganic fertilizer, T4-Farmers practice, T5-Enriched farmyard manure and T6-Improved farmyard manure.

The carbon sequestration potential for the soil in the experimental plots were calculated at $30^{th}$ and $60^{th}$ day (harvest) and expressed in t/h.

The carbon sequestration by the plant was calculated using the following formula [10]:

Carbon sequestered = Biomass x Carbon (%). The carbon sequestered by the fodder crops in the experimental plots were calculated at $60^{th}$ day (harvest) and expressed in t C / h.

The data collected on different parameters during the course of investigations were subjected to analysis using the analysis of variance (One-Way ANOVA) procedure of SPSS 11.5 to test the hypothesis and to find out, if there is any significant difference between manure treatments and carbon sequestration potential of fodder maize as per the procedure described by Gomez and Gomez [11].

## III. Results and Discussion

### *A. Soil Carbon Sequestration Potential*

Soil organic carbon content and soil carbon sequestration potential are presented in table I. It could be observed from the results, that there is a steady increase in soil organic carbon content in all the treatment groups from the date of sowing till harvesting ($60^{th}$ day). This increase in SOC might be due to the growth of plants which sequesters atmospheric $CO_2$ in to the plants and in turn returns the organic carbon in to the soil. These findings were in agreement with the findings of Gosh *et al.* [12]. The higher SOC observed in T5 (Enriched) and T6 (Improved) treatments, than the other treatment groups at 60$^{th}$ day can be attributed to the application of organic manure which contained decomposed materials having higher proportion of chemically intractable compounds leading to better yield and thereby better sequestration. This was in accordance with the finding of Srinivasarao *et al.* [13]. Similarly the higher SOC in T2 (Vermicompost) treatment than T1 (control) can be attributed to the application of organic manure resulting in higher organic carbon content over the control [14]. The higher SOC observed in T5 treatment was due to phosphorus solubilisation from rock phosphate in the enriched manure and well decomposed organic matter application resulted in significantly higher organic carbon content over control treatment which was in agreement with the findings of Pandey *et al.* [15].

Soil organic carbon content was higher in organic manure amended plots than the chemical fertilizer applied plots. This was in accordance with the findings of Gong *et al.* [16] and Kaur *et al*. [17]. Moreover, the increase of soil organic carbon in T6, T5, T3 and T4 treatments was due to the effect of organic manure which decomposes slowly resulting in more accumulation of carbon. The high lignin content of the organic manure is attributed to the higher content of the soil carbon [9]. In addition, the SOC content increase was due to carbon addition through the roots and crop residues, higher humification rate constant and lower decay rate [18]. Moreover, the root biomass along with farm yard manure acted as a source of organic matter which contributed tremendously for enhancing soil organic carbon content. Similarly, Gregorich *et al.* [19] opined that organic manure and compost, enhanced soil organic carbon more than that of the application of same amount of nutrients as inorganic fertilizers while studying the effects of changes in soil carbon under long term maize cultivation in monoculture and legume based rotation.

The soil carbon sequestration potential of fodder maize compared with control revealed that the carbon sequestration potential (CSP) of the soil increased from 30$^{th}$ day to 60$^{th}$ day of plant growth in different manure treatment plots. The increase of CSP could be due to high biomass of roots and plant residues, higher humification rate constant and direct application of organic matter through FYM [20] resulting in improved physico chemical and biological environment suitable for crop growth. Moreover, increased levels of long term stabilized humic material in organically amended plots and high content of soil carbohydrates in fertilized and farm yard manure treated plots played a crucial role in building SOC content. In a similar study on the maize-wheat cropping system, Kaur *et al.* [17] observed increasing soil CSP as the plant growth progressed. This shall be attributed to the increased plant growth that subsequently returned more organic carbon to the soil [12]. The significantly higher cumulative carbon sequestration potential was observed in T6 (4.06 t/ha), followed by T5 (4.01t/ha) and T2 (3.47 t/ha) treatments than T3, T4 and T1 treatment groups at 60$^{th}$ day. The decomposed manure (Vermicompost, Improved FYM manure and enriched FYM) at the time of application to the field had significantly higher organic carbon when compared to the conventional method of preparing manure. This could have been one of the reasons for higher soil CSP recorded in these treatments. Though many factors are responsible for dynamism of soil CSP, our limited study suggested that various parameters viz., the initial soil carbon in the soil before experimentation in the field, previous crop grown in the field and carbon content of the manure and quantity of manure applied for each treatment for equalisation of nitrogen content could have influenced the soil CSP. In our experiment, there was no significant difference among treatments with respect to initial soil OC, though values differed slightly. The higher CSP in T6 treatment shall be due to higher NPK content and well decomposed organic matter that provided readily available nutrients to the plants encouraging the plant growth which in turn increased carbon content of soil. This was in agreement with the findings of Srinivasarao *et al.* [13]. Similarly, T5 treatment had higher CSP than T3 and T4 treatment groups. This might be due to the addition of rock phosphate that resulted in ready availability of P which in turn enhanced plant growth and root biomass [21].The higher CSP observed in vermicompost treated plots can be attributed to the high proportion of carbon content, essential plant micronutrients viz., copper, iron, manganese and zinc and better soil environment made by vermicompost that encouraged better plant growth and productivity resulting in higher CSP. These findings were in concurrence with the findings of Suthar [22] and Premanik *et al.* [14].

### *B. Carbon content of Plant*

The plant organic carbon content and carbon sequestration potential of fodder maize is presented in Table II. Results revealed that the plant organic carbon content in T2, T5 and T6 treatments (56.73, 56.58, 56.52 per cent respectively) were significantly higher than T3(52.43 %), T4(51.73 %) and T1 (48.08 %) treatment groups. The values of plant organic carbon in fodder maize recorded in the present study were in concurrence with the values reported by Ayub *et al.* [23] in fodder maize (52.10 to 53.26 per cent). In general, as a plant grows there will be absorption of carbon-dioxide from the atmosphere which is stored in the leaves, stems and also the root.

TABLE I
IMPACT OF DIFFERENT MANURE TREATMENTS ON ORGANIC CARBON (%) AND CARBON SEQUESTRATION POTENTIAL (T/Ha) IN THE SOIL DURING DIFFERENT STAGES OF FODDER MAIZE

| Treatment | Percent soil organic carbon | | | Soil Carbon sequestration (t/ha) | | | Soil Carbon sequestration (t/ha) in different treatments in comparison with control. *(Initial carbon sequestration in control taken as '0')* | |
|---|---|---|---|---|---|---|---|---|
| | | | | Absolute | | Cumulative | | |
| | 0 day | 30 day | 60 day | 0 – 30 days | 30 – 60 day | 0 – 60 days | 30 day | 60 day |
| Control (T1) | 0.32±0.01 $^{a}$ | 0.36±0.01 $^{a}$ | 0.39±0.02 $^{a}$ | 0.75 $^{a}$ | 0.64 $^{a}$ | 1.39 $^{a}$ | 0.00 | 0.00 |
| Vermicompost (T2) | 0.33±0.01 $^{a}$ | 0.45±0.02 $^{c}$ | 0.50±0.02 $^{c}$ | 2.49 $^{b}$ | 0.98 $^{a}$ | 3.47 $^{bc}$ | 2.01 $^{b}$ | 2.36 $^{bc}$ |
| Inorganic fertilizer (T3) | 0.31±0.01 $^{a}$ | 0.40±0.01 $^{b}$ | 0.44±0.02 $^{b}$ | 1.93 $^{b}$ | 0.71 $^{a}$ | 2.64 $^{b}$ | 1.05 $^{a}$ | 1.11 $^{a}$ |
| Farmers practice (T4) | 0.31±0.01 $^{a}$ | 0.40±0.01 $^{b}$ | 0.45±0.01 $^{b}$ | 1.97 $^{b}$ | 1.10 $^{a}$ | 3.06 $^{b}$ | 0.97 $^{a}$ | 1.44 $^{ab}$ |
| Enriched FYM (T5) | 0.32±0.01 $^{a}$ | 0.46±0.02 $^{c}$ | 0.51±0.01 $^{c}$ | 2.98 $^{b}$ | 1.02 $^{a}$ | 4.01 $^{c}$ | 2.33 $^{b}$ | 2.72 $^{c}$ |
| Improved FYM (T6) | 0.33±0.01 $^{a}$ | 0.47±0.02 $^{c}$ | 0.52±0.01 $^{c}$ | 2.87 $^{b}$ | 1.19 $^{a}$ | 4.06 $^{c}$ | 2.41 $^{b}$ | 2.96 $^{c}$ |
| Level of significance | NS | ** | ** | ** | NS | ** | ** | ** |

$^{NS}$ - Non significant, ** Significant at $P < 0.01$; Mean bearing small letters in superscript differ significantly between treatments

TABLE II
IMPACT OF DIFFERENT MANURE TREATMENTS ON ORGANIC CARBON (%), BIOMASS (t/ha) AND CARBON ASSIMILATION POTENTIAL (t/ha) IN FODDER MAIZE

| Manure | Organic carbon (%) | Green fodder Yield (t/ha) | Dry matter yield(t/ha) | Carbon potential(t/ha) |
|---|---|---|---|---|
| Control (T1) | 48.02$^{a}$ | 34.05 $^{a}$ | 6.01 $^{a}$ | 2.88 $^{a}$ |
| Vermicompost (T2) | 56.73 $^{c}$ | 40.50 $^{c}$ | 7.15 $^{d}$ | 4.06 $^{d}$ |
| Inorganic fertilizer (T3) | 52.42 $^{b}$ | 40.20 $^{c}$ | 7.09 $^{c}$ | 3.72 $^{c}$ |
| Farmers practice (T4) | 51.73 $^{b}$ | 37.15 $^{b}$ | 6.56 $^{b}$ | 3.39 $^{b}$ |
| Enriched FYM (T5) | 56.58 $^{c}$ | 41.07 $^{c}$ | 7.25 $^{d}$ | 4.11 $^{d}$ |
| Improved FYM (T6) | 56.52 $^{c}$ | 41.63 $^{c}$ | 7.35 $^{d}$ | 4.15 $^{d}$ |
| Level of significance | ** | ** | ** | ** |

$^{NS}$ - Non significant, ** Significant at $P < 0.01$; Values bearing small letters in superscript differ significantly between treatments

During harvesting, due to abundant growth of the plant large amount of carbon gets accumulated in the plant and hence an increase in the carbon content was noticed in different manure treated plots. This was in agreement with the findings of Shehzad *et al.* [24], who studied the effects of nitrogen fertilization rate and harvest time on Maize (*Zea mays* L.), fodder yield and its quality attributes. They observed that the organic matter of the fodder maize increased from 89.20 percent at 45$^{th}$ day of harvest to 91.40 percent on 65$^{th}$ day, implying that the plant organic carbon increased from 51.86 percent on 45$^{th}$ day to 53.14 percent on 65$^{th}$ day. Further they stated that the organic carbon of the fodder increased as a result of maturation of plant due to the utilization of nutrients. The higher carbon content observed in treatment T2 was mainly due to the application of vermicompost. This can be attributed to the enhanced mineralization of soil nutrients due to higher microbial population and presence of nutrients in ionic form in the vermicompost making it a good source of plant nutrients that encouraged abundant plant growth, subsequently leading to accumulation of higher amount of carbon in the plant. These findings were in concurrence with the findings of Suthar and Singh [22]. In T5 treatment application of enriched manure had high P content which positively contributed to the biomass yield of maize. Also phosphate compounds acted as an energy currency in plants and played an important role in photosynthesis and the metabolism of carbohydrates [25]. Similarly, higher carbon content in T6 treatment might be due to the higher NPK content and well decomposed organic matter that provided readily available nutrients to the plants which encouraged the plant growth and root biomass. Further the effect of FYM which contained large amount of organic matter, and constant pressure on active microorganisms encouraged the fodder growth. Also it reduced the bulk density of the soil which in turn increased the organic carbon content of the fodder.

### *C. Green Fodder Yield of Fodder Maize*

The results revealed that the treatments T6, T5, T3 and T2 recorded higher green fodder yield than the other treatment groups. T6, T5, T3 and T2 treatments had a higher NPK content than other treatment groups leading to increased availability of soil nitrogen and other macro and micronutrients which might have enhanced meristematic growth and resulted in higher fodder yield. These were in accordance with the findings of Yong *et al.* [26] and Kannan *et al.* [27]. The fodder yield increase was due to the result of higher plant height, stem diameter and more dry matter production per plant. Also the two possible mechanisms was due to the regulatory role of nitrogen in production of amino acids and plant hormones responsible for cell division and enlargement and higher nitrogen facilitating optimum development of photosynthetic apparatus which captured the incident light more efficiently. This was in agreement with the findings of Tariq *et al.* [28]. The higher yield in T2 might be due to application of vermicompost with high amount of essential plant micronutrients viz., copper, iron, manganese and zinc as reported by Suthar [29] and Sable *et al.* [30]. The higher yield in T5 treatment shall be due to the availability of P in the T5 treatment group enriched with rock phosphate which might have positively contributed to biomass yield of maize. This finding was in agreement with the finding of Biswas *et al*. [21] who stated that phosphate compounds acted as an energy currency in plants and played an important role in photosynthesis and metabolism of carbohydrates.T6 treatment (improved farmyard manure) had the benefits of organic matter providing N, P, and K supply which resulted in improvement of microbial activity, better supply of macro and micro nutrients such as S, Zn, Cu and B [20]. Moreover, farm yard manure increased the availability of nutrients and improved the soil fertility and enhanced fodder production. This was in accordance with the findings of Ahmed *et al.* [31].

### *D. Carbon Sequestration Potential of Fodder Maize*

It was evident from the result T6 (4.15 t/ha), T5 (4.11 t/ha) and T2 (4.06 t/ha) treatments had significantly ($P<0.01$) higher carbon sequestration potential than other treatments. This could be due to higher carbon content and dry matter yield of fodder maize recorded by the treatments T6, T5, and T2. Similar results attributing higher CSP to higher biomass and carbon stock was earlier reported by Montagnini and Nair [32] and Yadava [33]. Similarly, Montagu *et al.*, [34] reported that biomass was an important indicator in carbon sequestration. Likewise Walker *et al.* [35] attributed that the above ground biomass had a high influence on the carbon sequestration potential in energetic crops. Our studies also suggested that plant organic carbon as well as the dry matter yield had positive influence on CSP individually and complementarily, in which case the offset in one may be compensated by the other.

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