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Manure treatment techniques to increase soil carbon sequestration potential in fodder maize (*Zea Mays L.*)

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ABSTRACT

The study was undertaken to find out the influence of different manure treatment methods on carbon sequestration potential of fodder maize. Significantly higher carbon sequestration potential was observed in improved, followed by enriched and vermicompost manure treatments than farmer's and inorganic fertilizer treatment groups at 60th day. 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, a potential green house gas.

Introduction

India, being a major country supporting a large share of livestock population in the world, it poses a serious problem for livestock waste disposal. Approximately, it is estimated that currently only 50 per cent of total dung is productively processed with remainder just applied to 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 as of now. Similarly, dung and other farm waste presently stored in open creates compounding problems. Agriculture and livestock accounts for 50 per cent of total methane emission (5 million tons per year), while the methane and nitrous oxide account for 23 and 22 per cent of India's current GHG emission respectively (Harsdorff, 2012). GHG emission is considered as one of the major factors causing global warming and global concern particularly among countries like India where livestock population is more. The present study is undertaken to evaluate better treatment methods for quick disposal of dung to avoid such GHG emission. Maintenance of high concentration of soil organic carbon (SOC) has profound effect on soil quality. It encourages aggregation, increase water retention, nutrient supply and microbial activity, by improving soil fertility and productivity (Karlen *et al*., 1997), 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 for example conservation tillage, application of fertilizers, organic amendments, crop rotation and improved residue management (Lal, 2003). Among these practices, the benefits of balanced application of mineral fertilizers and manure in maintaining and increasing levels of SOC in agricultural soil (Rudrappa *et al*., 2005) 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 (Lal *et al*., 1998). 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 (Lal, 2004). In this connection, the present study was also planned to address the issue of evaluating fodder maize for its carbon sequestration potential for the benefit of offsetting increase in carbon level in the atmosphere. Hence, with the above background information, the present study has been undertaken to study the influence of different manure treatment methods on soil carbon sequestration potential of fodder maize.

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 dairy farm at Mandapam village, Kancheepuram district, located at 70 km south of Chennai city at an altitude of 35.1 m above MSL, with a latitude of 12°.41' 08.26'' N and longitude of 79° 55' 27.39'' E. The climate is warm and humid, classified as "tropical maritime monsoon" type. Based on the past five years meteorological 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 physicochemical properties. The study area had the 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 5.75 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

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6.25 t/ha, T5 as enriched farmyard manure (Composted enriched with rock phosphate in manure pit) with 5.85 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 6.10 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 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 the 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 pestle and mortar, ground 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 Analytikjena 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 (Manrique and Jones, 1991).

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 (Pathak *et al*., 2011).

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 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 (1984).

Result and Discussion

Soil organic carbon content and soil carbon sequestration potential were presented in table 1. It could be observed from the results that 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 return the organic carbon in to the soil. These findings were in agreement with the findings of Gosh *et al.* (2006). The higher SOC observed in T6 (Improved), T5 (Enriched) and T2 (Vermicompost) treatments than other treatment groups at 60^{th} day shall 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.* (2012). Similarly the higher SOC in T2 (Vermicompost) treatment than T1 (control) shall be attributed to the application of organic manure resulting in higher organic carbon content over control (Premanik *et al.*, 2009). 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.* (2009).

Soil organic carbon content was higher in organic manure amended plots than the chemical fertilizer applied plots (Gong *et al.*, 2009). Also the increased root biomass and crop residue was due to enhancement of carbon through FYM. This was in accordance with the findings of Kaur *et al*. (2008). Moreover, the increase of soil organic carbon in T6, T5, and T2 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 attributed to the higher content of the soil carbon (Pathak *et al.* 2011). 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 (Enke liu *et al.*, 2010). 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.* (2001) opined that organic manure and compost enhanced soil organic carbon more than the application of same amount of nutrients as inorganic fertilizers while studying the effects of changes in soil carbon under long term maize 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 was due to high biomass of roots and plant residues, higher humification rate constant and direct application of organic matter through FYM (Bhattacharya *et al.*, 2008) 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.* (2008) 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 (Ghosh *et al.*, 2006).

Table 1. Effect of different manure treatments on soil organic carbon (%) and carbon sequestration potential (t/ha) in the soil during different stages of fodder maize growth

Manure treatment	Percent soil organic carbon			Soil Carbon sequestration (t/ha) in different treatments in comparison with control. *(Initial carbon sequestration in control taken as '0')*	
	0 day	30 day	60 day	30 day	60 day
Control (T1)	0.31^{a}	0.34^{a}	0.37^{a}	0.00	0.00
Vermicompost (T2)	0.32^{a}	0.43^{bcd}	0.48^{c}	1.91^{b}	2.33^{b}
Inorganic fertilizer (T3)	0.30^{a}	0.38^{b}	0.42^{b}	0.94^{a}	1.01^{a}
Farmers practice (T4)	0.31^{a}	0.39^{bc}	0.43^{b}	1.01^{a}	1.30^{a}
Enriched FYM (T5)	0.33^{a}	0.45^{cd}	0.49^{c}	2.41^{b}	2.62^{bc}
Improved FYM (T6)	0.32^{a}	0.46^{d}	0.50^{c}	2.70^{b}	2.87^{c}
Level of significance	NS	**	**	**	**

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

The significantly higher carbon sequestration potential was observed in T6 (2.87 t/ha), followed by T5 (2.62 t/ha) and T2 (2.33 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.* (2012). 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 (Biswas *et al.*, 2006).The higher CSP observed in vermicompost treated plots shall 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 (2009) and Pramanik *et al.* (2009).

Conclusion

It was concluded that application of improved, enriched and vermicompost manure sequestered higher carbon in soil from the atmosphere than other treatments, implying the benefit for reducing the impact of carbon, a potential green house gas.

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