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# Impact of soil amendments on greenhouse gas emissions in maize (*Zea mays* L.)

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**Abstract**
A field experiment was carried out at College Farm, College of Agriculture, Rajendranagar, PJTSAU, Hyderabad, Telangana state, to evaluate the impact of different soil amendments on greenhouse gas (GHG) emissions in maize crop. $CO_2$, $N_2O$ and $CH_4$ fluxes from the soil surface were measured thrice a week during the crop growing season using static flux chambers and GC gas analyzer. Adjustments in sampling dates and frequency were made to include specific events such as rainfall, irrigation, temperature, N application or tillage. The application of vermicompost, tanksilt, (Farm Yard Manure) FYM, RDF (Recommended Dose of Fertilizers) and biochar decreased the cumulative $CO_2$ emission (126.3, 124.4, 121.6, 111.13 and 109.18 kg $Co_2$-C $ha^{-1}$) respectively compared to the control (134.12 kg $Co_2$-C $ha^{-1}$). The cumulative $CH_4$ emission was recorded in the order of vermicompost > control > biochar > RDF > tanksilt > FYM. The application of RDF, tanksilt, FYM, vermicompost and biochar increased the cumulative nitrous oxide ($N_2O$) emission (1.58, 0.97, 0.78, 0.67 and 0.38 kg $ha^{-1}$) respectively compared to the control (0.037 kg $ha^{-1}$). The application of RDF, tanksilt, FYM, vermicompost and biochar increased the $N_2O$ emission factor (0.775, 0.41, 0.28, 0.243 and 0.127%) respectively. Highest global warming potential (GWP) and greenhouse gas intensity (GHGI) was observed in the RDF applied plots. Lowest GWP and GHGI being observed in the control and biochar applied plots respectively.

**Keywords:** Biochar, FYM, vermicompost, tanksilt, GHG emissions, global warming potential and $N_2O$ emission factor

## Introduction

The major environmental problem today is the global warming due to accumulation of gases like $CO_2$, $CH_4$ and $N_2O$, chlorofluoro carbons along with water vapour in the atmosphere causing greenhouse effect through trapping outgoing thermal radiation and depletion of ozone layer in stratosphere, affecting several aspects of humanity on planet earth, due to increased temperature (0.3-0.6 °C) at the earth's surface. Agriculture accounts for approximately 10–12% of total global anthropogenic emissions of GHG, which amounts to 60 and 50% of global nitrous oxide ($N_2O$) and methane ($CH_4$) emissions, respectively (Smith *et al.*, 2007) [19].

Biochar is a solid by-product resulting from partial pyrolysis, where biomass is heated with a minimum or absence of oxygen. Biochar is formed from crop residues and animal manures. Biochar addition to soils significantly decreases soil bulk density, increased microbial respiration as well as $CO_2$ and $CH_4$ emissions (Wang *et al*. 2012) [23]. They also found that a decreased $N_2O$ emissions and increase soil pH and organic C by addition of biochar. Climate change and global warming have worldwide adverse consequences. Biochar production and its use in agriculture can play a key role in climate change mitigation and help improve the quality and management of waste materials coming from agriculture and forestry. Biochar is currently a subject of active research worldwide because it can constitute a viable option for sustainable agriculture due to its potential as a long term sink for carbon in soil and benefits for crops (Alburquerque *et al*., 2013) [1]. Biochar application resulted in decreased or unaltered rates of $CH_4$ oxidation, with no increases observed in $CH_4$ oxidation or production activity. Kimetu and Lehmann (2010) [6] reported a finding that application of biochar led to a reduction in $CO_2$ evolution from (Soil organic carbon) SOC-poor soil but to an increased $CO_2$ evolution from SOC-rich soil.

The sediment washed off through runoff from catchment area gets deposited in tank beds and generally referred as Tank Silt. Sediment removal from water tanks is an important indigenous natural resource management practice especially in Telangana state, India.

The sediments are potentially capable of supporting annual crop due to their high natural fertility and water holding capacity. A bulk of sediment deposited in water bodies is generally less of sand and silt but more of clay. Its application to soil makes good use of sediment containing clay, silt, nutrients and organic matter and brings them back to the crop lands. Thus, de-silting and application of tank silt are the two important options in order to restore rain water storage capacity of water harvesting structures and improvement of soil fertility of marginal crop lands (Bhanavase *et al.,* 2011) [4].

Mission Kakatiya with a tag line 'Mana Ooru – Mana Cheruvu' (our village–our tank) is a recently launched program of the Government of Telangana. This program aims to renovate around 46,000 irrigation tanks in Telangana state over a period of 5 years from 2014-15. With around Rs. 22,000 crores estimated budget, the Government is pooling resources from own funds, Central Government, NABARD and other financing agencies. While restoring tanks to their functional capacity, emphasis is also placed on de-silting and utilizing the silt for improving soil fertility in agricultural lands. Farmers are being motivated to come forward and voluntarily participate in transporting the silt to their lands. Hence, tanksilt has been evaluated as one of the amendments to test its effect on soil moisture content and soil fertility as well as on GHG emissions. However, the tanksilt should be pre analysed for heavy and pollutant element status before applying to the field.

According to a pilot study conducted by ICRISAT, impact of silt application on soil is tremendous. Addition of tank silt in fields has improved available water content. Moisture retention has gone up by 4-7 days (Osman, 2008) [14]. Improvement in clay content will not only retain higher moisture but will also reduce the losses of nutrients through leaching, because of improved cation exchange capacity.

Total $N_2O$ and $CH_4$ emissions were lower from the FYM treatments with straw added than those without. One reason for this could be the effects of the higher C: N ratio and dry matter content measured in the FYM with added straw. The higher C: N ratio could reduce mineralization and FYM decomposition and so reduce the overall emissions (Yamulki, 2006) [24]. Addition of vermicompost to soil increased $CO_2$ emission compared to the urea applied soil and unamended soil. Emission of $N_2O$ was in the order: Vermicompost soil > urea applied soil > un amended soil (Rodriguez *et al.,* 2011) [17].

After every dose of N application, the $N_2O$-N flux increased due to availability of substrate for nitrification. Denitrification might have taken place in some anaerobic microsites in the soil, resulting in $N_2O$-N flux (Arah and Smith, 1989) [2]. The $N_2O$-N production through denitrification was limited due to high $O_2$ concentration, which is toxic to denitrifiers. Substantial increase in $N_2O$ fluxes was observed after the applications of irrigation, which enhanced activities of nitrifiers and denitrifiers in soil (Pathak *et al.,* 2002) [15].

The net exchange of $CH_4$, $N_2O$ and $CO_2$ in terms of $CO_2$ equivalents between soils and the atmosphere comprises the net global warming potential (NGWP) of a cropping system (Mosier *et al*., 2006) [13]. The greenhouse gas intensity (GHGI) is being used to relate agricultural production to global warming potential (Zhang *et al*., 2010) [25]. However, no knowledge is available about the impacts of soil amendments on GHGI in maize farming systems. A positive GHGI number indicates a net source of $CO_2$ equivalents per tonne of yield and a negative value indicates net sinks of GHG to the soil.

The objectives of this study is to gain a holistic insight into the effects of soil amendments on maize productivity and on net GHGs emissions during the whole maize growing season.

## Material and Methods

**Experimental site and design:** Maize variety 900-M-GOLD was cultivated during rabi 2014-15 in Randomised Block Design (RBD) with 6 treatments replicated four times at the college farm, College Of Agriculture, Rajendranagar, Hyderabad, Southern Telangana Zone, India. The soil is sandy loam in texture, slightly alkaline, non-saline and medium in organic carbon content. Treatments consist of $T_1$-vermicompost @ 5 t $ha^{-1}$,$T_2$-FYM @ 10 t $ha^{-1}$, $T_3$-tanksilt @ 50 t $ha^{-1}$, $T_4$- biochar @10 t $ha^{-1}$,$T_5$- control (without any fertilizer),$T_6$- RDF (NPK-200, 60, 50 kg $ha^{-1}$). Recommended Dose of Fertilizers was commonly applied from treatment $T_1$ to $T_4$. Maize crop variety 900-M GOLD was cultivated with a spacing of 75 x 20 cm in plots of 8 x 5 $m^2$.

## Green House Gas Emissions

### Collection of Green House Gases from maize field and analysis

$CO_2$, $N_2O$ and $CH_4$ fluxes from the soil surface were measured thrice a week during the crop growing season using static flux chambers and GC gas analyzer. Adjustments in sampling dates and frequency were made to include specific events such as rainfall, irrigation, temperature, N application or tillage.

A 10-cm-high vented rectangular aluminium chamber with a sampling port was placed in a water channel that was welded onto an anchor (78.6 × 39.3 × 10 cm) that had been inserted 10 cm into the soil at each sampling site. Anchors were set perpendicular to the crop row so that the crop row and inter-row were contained within each chamber. Flux measurements were always conducted between 08:00 AM to 12:00 PM hours to minimize diurnal variation in the flux pattern. On each sampling day, the sequence of gas measurements in the treatments was randomized to avoid bias due to rising temperature during the morning hours. Duplicate flux measurements were made within each replicate of each treatment plot. The plants were cut off when they became too tall to fit inside the chambers. Gas samples from inside the chambers were collected by syringe at 0, 15, and 30 min after installation. Gas samples (40 ml to ensure over pressure of sample in the tubes) were then injected into 20-mL evacuated tubes that were sealed with butyl rubber septa and transported to the laboratory in CRIDA (Central Research Institute for Dryland Agriculture, Santhosh nagar, Hyderabad.) for analysis by gas chromatography. The gas chromatograph used was a fully automated instrument (Varian 3800; Varian, Inc., Palo Alto, CA) equipped with an electron capture detector (ECD), flame ionization detector (FID) and thermal conductivity detector (TCD) to measure $N_2O$, $CH_4$ and $CO_2$ respectively. Fluxes were calculated from the linear or nonlinear increase in concentration (selected according to the emission pattern) in the chamber head space with time (Livingston and Hutchinson, 1995) [10]. Estimates of daily GHG emissions between sampling days were made using a linear interpolation between adjacent sampling dates.

### $N_2O$ emission factor

$N_2O$ emission factor (%) was computed by using following equation (Zhang *et al*., 2012) [26]

$$N_2O \text{ emission factor} = \frac{N_2O \text{ emission in amendment plot} - N_2O \text{ emission in control}}{\text{N dose}} \times 100$$

**Global warming potential**

Global warming potential (GWP) was computed by using following equation (Zhang *et al.*, 2012) [26]

GWP (kg $ha^{-1}$) = Emission of $CO_2$ (kg $ha^{-1}$) + Emission of $CH_4$ (kg $ha^{-1}$) x 21 +Emission of $N_2O$ (kg $ha^{-1}$) x 310.

**Greenhouse gas intensity (GHGI)**

GHGI was computed by using equation (Zhang *et al.*, 2012) [26]

GHGI = GWP/Y

Where, GWP is Global warming potential, Y is grain yield of maize in t $ha^{-1}$ and GHGI is the total overall emission intensity with grain production (kg $CO_2$-equivalents $t^{-1}$).

**Nitrogen content of amendments:** The nitrogen contents of different amendments used were given in Table 1.

**Table 1:** Nitrogen content of different amendments

| Amendment | N content (%) |
|---|---|
| Tanksilt | 0.030 |
| Vermicompost | 1.20 |
| FYM | 0.61 |
| Biochar | 0.71 |

Tanksilt was taken from the one of the popular tank at Hyderabad. Biochar for this experiment is prepared from *Prosopis juliflora* (locally known as Sarkar tumma) which is a thorny Shrub mostly grown on waste land and spreads mainly due to its inbuilt mechanism to overcome adverse conditions of like drought and salt.

## Results and Discussion

### Green House Gas Emissions

### Cumulative $CO_2$ emission

Data pertaining to the cumulative $CO_2$ emission was presented in Table 2. A perusal of the data indicates that highest cumulative $CO_2$ emission was observed in control *i.e.*, without any fertilizer application followed by vermicompost applied plots and lowest in the biochar applied plots. The cumulative $CO_2$ emission was recorded in the order of control > vermicompost > tanksilt > FYM > RDF > biochar. The application of vermicompost, tanksilt, FYM, RDF and biochar decreased the cumulative $CO_2$ emission (126.3, 124.4, 121.6, 111.13 and 109.18 kg $Co_2$-C $ha^{-1}$) respectively as compared to the control (134.12 kg $Co_2$-C $ha^{-1}$). The application of different amendments *viz.*, tanksilt, vermicompost and FYM along with RDF increased the cumulative $CO_2$ emission compared to the RDF alone but the application of biochar along with RDF decreased the cumulative $CO_2$ emission compared to the RDF alone.

Biochar application @ 10 t $ha^{-1}$ recorded significantly lower cumulative $CO_2$ emission of 109.18 kg $CO_2$-C $ha^{-1}$. Spokas *et al.* (2009) [21, 22] observed reduced emission of $CO_2$ from a silt loam soil amended with wood chip biochar compared to un-amended control. Liu *et al.* (2011) [11] reported that $CH_4$ and $CO_2$ emissions were reduced by 51 and 91%, respectively, when soil was amended with bamboo (*Bambuseae spp.*) and rice straw biochar pyrolyzed at 600 °C. Nitrogen fertilization increased the respiration of the soil-plant ecosystem by increasing the accumulation of biomass and improving the bioavailability of C to soil microbes, which is in good agreement with previous results (Raich and Schlesinger, 1992) [16]. The addition of biochar did not increase the ecosystem respiration during either crop season in the upland soil which is in accordance with Knoblauch *et al.* (2008) [7] who found that charred rice residues had no effect on the carbon mineralization or $CO_2$ emissions of paddy soil over about two years of oxic incubation. The vermicompost had all characteristics of a mature product and did not stimulate microbial activity when added to soil (Rodriguez *et al.*, 2011) [17]. The effect of vermicompost on $CO_2$ emission is presumably mostly indirect. Vermicompost improves soil structure and the continuity of pore space eases root penetration and flow of water and gases (Marinari *et al.*, 2000) [12]. Additionally, vermicompost stimulated microbial activity in the rhizosphere. The direct effect of vermicompost is due to mineralization of the vermicompost might also have contributed although the vermicompost was mature, *i.e.* most easily decomposable organic material was mineralized (Luqueno *et al.*, 2009) [11].

### Cumulative $CH_4$ emission

Data pertaining to the cumulative $CH_4$ emission was presented in Table 2. The application of biochar, RDF, tanksilt and FYM decreased the cumulative $CH_4$ emission (0.051, -0.041, -0.097 and -0.151 kg $ha^{-1}$) respectively compared to the control (0.059 kg $ha^{-1}$). Significant decrease of $CH_4$ emission was noticed with FYM application but the decrease in emission with RDF, tanksilt and biochar was not significant. Increase in soil aeration and porosity by biochar amendment may decrease production of $CH_4$ from soil as anoxic conditions created may increase oxidation of $CH_4$ (Zwieten *et al*., 2009) [27]. Shuji and Tanaka (2014) [18] reported that $CH_4$ flux decreases in the soil with biochar application. With applying biochar in the soil, changing the anaerobic to aerobic state or absorption of $CH_4$ with the biochar brought possibly in this decrease.

From the data it was evident that highest cumulative $CH_4$ emission was observed in the vermicompost applied plots followed by control and lowest being the FYM applied plots. The cumulative $CH_4$ emission was recorded in the order of vermicompost > control > biochar > RDF > tanksilt > FYM. The application of different amendments *viz.*, vermicompost and biochar along with RDF increased the cumulative $CH_4$ emission compared to the RDF alone but the application of tanksilt and FYM along with RDF decreased the cumulative $CH_4$ emission compared to the RDF alone.

### Cumulative $N_2O$ emission

Data pertaining to the cumulative $N_2O$ emission was presented in Table 2. A perusal of the data indicates that significantly lower cumulative $N_2O$ emission of 0.037 kg $ha^{-1}$ was recorded with the control *i.e.*, without any fertilizer application. The application of RDF, tanksilt, vermicompost, FYM and biochar increased the cumulative $N_2O$ emission (1.58, 0.97, 0.67, 0.39 and 0.38 kg $ha^{-1}$) respectively compared to the control (0.037 kg $ha^{-1}$). By the application of RDF, the immediate release of $NO_3$ will occur and it was reduced to nitrous oxide and $N_2O$ emission was increased. But the application of amendments release the nitrogen slowly and most of released nitrogen utilized by plants only. So, the $N_2O$ emission was reduced by the application of amendments compared to RDF. From the data it was evident that highest cumulative $N_2O$ emission was observed in the RDF applied plots followed by tanksilt applied plots and lowest being the control *i.e.*, without any fertilizer application. The cumulative $N_2O$ emission was recorded in the order of RDF > tanksilt >

vermicompost > FYM > biochar > control. Liu *et al.* (2005) [8] reported that $N_2O$ emission was increased linearly with N application rate. Ball *et al.* (2004) reported that higher annual $N_2O$ emission under NPK fertilizer than with cattle slurry injected to 5 cm depth. Pathak *et al.* (2002) [15] reported that application of FYM with urea reduced the $N_2O$ emission from 0.38% of applied N with urea alone to 0.32% of applied N in rice-wheat system. This lower $N_2O$ emissions with biochar might be due to increase in microbial immobilisation of the available N in the soils with biochar. Biochar additions generally suppressed the $N_2O$ production (Spokas and Reicosky, 2009) [21, 22]. Addition of organic material, *i.e.* waste water sludge or vermicompost, sharply increased the emission of $N_2O$ compared to unamended soil (Rodriguez *et al.*, 2011) [17].

**Table 2:** Soil amendments impact on cumulative greenhouse gas emission (kg $ha^{-1}$) in maize crop.

| Treatments | Cumulative Greenhouse gas emission | | |
|---|---|---|---|
| | $CO_2$ | $CH_4$ | $N_2O$ |
| $T_1$ : Vermicompost | 126.30 | 0.093 | 0.67 |
| $T_2$ : FYM | 121.60 | -0.151 | 0.78 |
| $T_3$ : Tanksilt | 124.40 | -0.0971 | 0.97 |
| $T_4$ : Biochar | 109.18 | 0.051 | 0.38 |
| $T_5$ : Control | 134.12 | 0.059 | 0.037 |
| $T_6$ : RDF | 111.73 | -0.041 | 1.5872 |

(RDF was commonly applied from treatment $T_1$ to $T_4$.)

### $N_2O$ emission factor

A perusal of the data indicated that RDF recorded significantly higher percent of $N_2O$ emission factor of the fertiliser applied (Table 3). RDF, tanksilt, FYM, vermicompost and biochar recorded 0.77, 0.43, 0.28, 0.24 and 0.12% respectively of applied nitrogen was lost as $N_2O$ emissions. The lowest loss of% N fertilizer applied was observed with soil amendments *viz*., biochar followed by vermicompost and FYM along with RDF application as compared to the RDF alone. The lower $N_2O$ emission of the fertilizer applied in biochar might be due to immobilization of nitrogen by the binding of nitrogen to biochar. Zhang *et al.* (2012) [26] reported that emission factor for $N_2O$ was decreased by approximately 18% and 53% under biochar amendment at 20 t $ha^{-1}$ and 40 t $ha^{-1}$ with N fetililization ( 300 kg N $ha^{-1}$) respectively compared to no biochar amendment.

**Table 3:** Soil amendments impact on $N_2O$ emission factor (%) in maize crop

| Treatments | $N_2O$ emission factor (%) |
|---|---|
| $T_1$ : Vermicompost | 0.243 |
| $T_2$ : FYM | 0.280 |
| $T_3$ : Tanksilt | 0.433 |
| $T_4$ : Biochar | 0.127 |
| $T_5$ : Control | - |
| $T_6$ : RDF | 0.775 |

(RDF was commonly applied from treatment $T_1$ to $T_4$.)

### Global warming potential

A perusal of the data indicates that significantly the highest global warming potential of 602.8 kg $ha^{-1}$ was recorded with the RDF application (Table 4). The application of RDF, tanksilt, vermicompost, FYM and biochar increased the global warming potential (602.8, 423.0, 336.0, 360.2 and 228.0 kg $ha^{-1}$) respectively compared to the control (146.8 kg $ha^{-1}$).

From the data it was evident that highest global warming potential was observed in the RDF applied plots followed by tanksilt applied plots and lowest being the control *i.e*., without any fertilizer application. Among the amendments lowest global warming potential was observed in biochar application plots. Zhang *et al.* (2012) [26] reported that compared to N fertilized plots (300 kg N $ha^{-1}$), the overall total GWP was decreased by 9.8% under plots amended with biochar 20 t $ha^{-1}$+ N fertilization and by 41.5% under plots amended with biochar 40 t $ha^{-1}$ + N fertilization in maize crop.

The application of different amendments *viz*., tanksilt, vermicompost FYM and biochar along with RDF decreased the global warming potential compared to the RDF alone. This lower GWP in amendments plots was due to lower GHG emissions from these plots.

**Table 4:** Soil amendments impact on global warming potential (kg $ha^{-1}$) in maize crop.

| Treatments | Global warming potential (kg $ha^{-1}$) |
|---|---|
| $T_1$ : Vermicompost | 336.0 |
| $T_2$ : FYM | 360.2 |
| $T_3$ : Tanksilt | 423.0 |
| $T_4$ : Biochar | 228.0 |
| $T_5$ : Control | 146.8 |
| $T_6$ : RDF | 602.8 |

(RDF was commonly applied from treatment $T_1$ to $T_4$.)

### Yield

The application of different amendments resulted in significantly more grain yield than RDF applied plots and control (Table 5). The grain yield of maize ranged from 3.547 t $ha^{-1}$ (control) to 9.054 t $ha^{-1}$ (tanksilt). The lowest yield was produced from control plot where fertilizer was not applied. In RDF applied plots 5.750 t $ha^{-1}$ of maize grain yield was recorded. Among the various amendments, the grain yield of maize followed the order of tanksilt > vermicompost > biochar > FYM.

All the amendment application resulted in significant increase in grain yield over the RDF applied plots but the application of FYM was on par with the RDF applied plots. The increase in grain yield was 33.14, 30.38, 15.94 and 10% in tanksilt, vermicompost, biochar and FYM applied plots respectively over RDF applied plots (5.750 t $ha^{-1}$). An increase in grain yield in biochar amendments plots include the effect of biochar on soil physio-chemical properties like enhance water holding capacity, increased cation exchange capacity (CEC), and providing a medium for adsorption of plant nutrients and improved conditions for soil micro-organisms (Sohi *et al.*, 2009). The better growth in terms of leaf area index, dry matter accumulation and more cobs/plant could be the reason for increased grain yield (Joshi *et al.*, 2013) [5].

**Table 5:** Soil amendments impact on grain yield (t $ha^{-1}$) of maize.

| Treatments | Yield (t $ha^{-1}$) |
|---|---|
| $T_1$ : Vermicompost | 7.497 |
| $T_2$ : FYM | 6.325 |
| $T_3$ : Tanksilt | 9.054 |
| $T_4$ : Biochar | 6.667 |
| $T_5$ : Control | 3.547 |
| $T_6$ : RDF | 5.750 |
| CD (P = 0.05) | 0.741 |
| SEm± | 0.246 |

(RDF was commonly applied from treatment $T_1$ to $T_4$)

**Greenhouse gas intensity (GHGI)**

As shown in Table 6, the highest greenhouse gas intensity of 104.85 kg $CO_2$-e $t^{-1}$ was recorded with the RDF application. The application of RDF, tanksilt, vermicompost and FYM increased the greenhouse gas intensity (104.85, 46.72, 44.81 and 56.95 kg $CO_2$-e $t^{-1}$) respectively compared to the control (41.39 kg $CO_2$-e $t^{-1}$). But the biochar application decreased the greenhouse gas intensity (34.20 kg $CO_2$-e $t^{-1}$) compared to the control (41.39 kg $CO_2$-e $t^{-1}$).

From the data it was evident that highest greenhouse gas intensity was observed in the RDF applied plots followed by FYM applied plots and lowest being the biochar applied plots. The application of different amendments *viz*., tanksilt, vermicompost, FYM and biochar along with RDF decreased the greenhouse gas intensity compared to the RDF alone. This lower GHGI in amendments plots was due to lower GWP and higher grain yield from these plots. Zhang *et al.* (2012) [26] reported that compared to N fertilized plots (300 kg N $ha^{-1}$), GHGI was decreased by 23.8% under plots amended with biochar 20 t $ha^{-1}$+ N fertilization and by 47.6% under plots amended with biochar 40 t $ha^{-1}$ + N fertilization in maize crop. Both GWP and GHGI indicate that when appropriate crop production levels are achieved, net $CO_2$ emissions are reduced (Mosier *et al*., 2006) [13].

**Table 6:** Soil amendments impact on Greenhouse gas intensity (kg $CO_2$-equivalents $t^{-1}$) in maize crop.

| Treatments | Greenhouse gas intensity (kg $CO_2$-e $t^{-1}$) |
|---|---|
| $T_1$ : Vermicompost | 44.81 |
| $T_2$ : FYM | 56.95 |
| $T_3$ : Tanksilt | 46.72 |
| $T_4$ : Biochar | 34.20 |
| $T_5$ : Control | 41.39 |
| $T_6$ : RDF | 104.85 |

(RDF was commonly applied from treatment $T_1$ to $T_4$)

**Conclusion**

Application of biochar along with RDF decreased the cumulative $CO_2$ emission compared to the RDF alone. The cumulative $CH_4$ emission was recorded in the order of vermicompost > control > biochar > RDF > tanksilt > FYM. Increase in soil aeration and porosity by biochar amendment may decrease production of $CH_4$. The cumulative $N_2O$ emission was recorded in the order of RDF > tanksilt > FYM > vermicompost > biochar > control. By the application of RDF, the immediate release of $NO_3$ will occur and it was reduced to nitrous oxide and $N_2O$ emission was increased. But the application of amendments release the nitrogen slowly and most of released nitrogen utilized by plants only. So, the $N_2O$ emission was reduced by the application of amendments compared to RDF. The application of different amendments *viz*., tanksilt, vermicompost FYM and biochar along with RDF decreased the $N_2O$ emission factor compared to the RDF alone. Highest global warming potential was observed in the RDF applied plots followed by tanksilt applied plots and lowest being the control *i.e*., without any fertilizer application. Higher GWP in RDF plot was due to high GHG emissions especially $N_2O$ emission from RDF applied plot. The lower GWP in amended plots was due to decrease in GHG emissions from these plots. Among the amendments lowest global warming potential was observed in biochar application plots. Among the various amendments, the grain yield of maize followed the order of tanksilt > vermicompost > biochar > FYM. The application of different amendments *viz*., tanksilt, vermicompost, FYM and biochar along with RDF decreased the greenhouse gas intensity compared to the RDF alone.

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