Ann. For. Res. 67(1): 178-189, 2024
ISSN: 18448135, 20652445
ANNALS OF FOREST RESEARCH
www.e-afr.org

DYNAMICS OF PLANT NUTRIENTS AND GREENHOUSE GASES DURING THE PROCESS OF COMPOST FORMATION

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Abstract

Organic amendments play an important role to increase soil organic matter (SOM). Organic materials including crop residues, manures, composts and other rural and urban biogenic waste has been suggested to enhance soil nutrient bioavailability and to increase fertilizer use efficiency. However, the effect of the organic amendments on nutrient availability depends on their decomposability and indigenous nutrient concentration. Most sensible and profitable way to avoid wasting of useful natural resources without creating environmental problems is composting which produce a high quality and low cost organic amendment from organic waste materials. The study was mainly conducted to evaluate the effects of compost prepared from different waste materials on greenhouse gas emission and nutrients availability in soil. The specific objective of the study was to assess GHG emission from compost and nutrient release pattern during composting. Compost was prepared in pits using raw materials viz. farmyard manure (FM), poultry manure (PM) and green manure (GM) for 90 days. In the study, samples of compost were analyzed for total N, total P, total K and greenhouse gases emission. In the second study, The treatments applied

were; i) control, ii) PM, iii) FM, iv) GM, v) PM+FM 1:1, vi) PM+GM 1:1, vii) FM+GM 1:1, viii) PM+FM+GM 1:1:1. All the treatments were replicated three times following completely randomized design (CRD) lay out. The samples collected on 0, 15, 30, 45, 60, 75 and 90 days. The results indicated that nutrient release was maximum in compost having three types of material used for composting while greenhouse gases release was minimum in these treatments. Release of greenhouse gases were mainly dependant on temperature and decomposition rate of organic matter.
Key words: Compost, greenhouse gases, Organic amendments

Introduction

Composting is certainly a very important primeval process. The practice of manure composting is as ancient as in biblical times and remained in practice until the mid of 20th century when its importance was vanquished by the onset of chemical fertilizers industry (Larney et al., 2006). In addition to carbon dioxide (CO2), nitrous oxide (N2O) is another major greenhouse gas (GHG) that contributes to global warming (IPCC 2023). The degradation of the ozone layer in the stratosphere is also attributed to nitrous oxide emissions. Nitrous oxide has a lengthy lifetime of 114 years and a global warming potential 298 times more than CO2 over a 100-year time horizon. Among different types of composts soils amendments are done with 3.8×109 Mg yr-1 of plant residues, 7×109 Mg yr-1 of animal manures and 10×107 Mg/yr of biosolids worldwide. This practice is comprised of many advantages (improved plant growth, high yield, microbiota & its activity and C contents) as well as some disadvantages (GHG emissions and nutrient eutrophication). Among the GHG CH_4 and N_2O is 21 and 310 era having more contribution towards global 10 warming correspondingly (Rodhe, 2011).

MATERIALS AND METHODS

The experiment was about different treatments in which combinations of compost types was prepared. These treatment combinations were mixed in particular manner and kept in pits, each of which was 1x 1 x1 m3 dimension. By adding water manually the moisture was maintained up to 40%. Temperature was recorded at 3 days interval. For proper aeration composts were inverted at 15 days of interval to increase the microbial decomposition. At 15 days interval samples were drained and analyzed for total nitrogen, total carbon, and greenhouse gases emission. Composting was continued till complete conversion of feedstock into compost and a C:N ratio of 10:1 was attained. Treatment combinations were as under:

1. Poultry manure (PM)
2. Farm yard manure (FM)
3. Green waste (GW)
4. PM + FM at ratio of 1:1
5. PM + GW at ratio of 1:1
6. FM + GW at ratio of 1:1
7. PM + FM + GW at ratio of 1:1:1

At maturity the products were analyzed for available NPK. With respect to available plant nutrients and greenhouse gas emission two best performing products were selected for further incubation studies.

Greenhouse gases the samples were taken from air tight pits with the help of syringes transferred to air tight voiles and carried to the laboratory for further analysis. Gas chromatography was used to evaluate the gas samples for CO_2, N_2O, and CH_4 as per Allen *et al* (2007)

RESULTS AND DISCUSSION

Seven treatments viz: Poultry manure (PM), Farmyard manure (FYM), Green waste (GW) and combination of PM+FYM, PM+GW, FYM+GW, PM+FYM+GW were planned for compost preparation and characterization with 15 days of interval for the determination of macronutrients viz: nitrogen, phosphorus and potassium, greenhouse gases viz: CO_2, N_2O and CH_4, chemical properties, EC and temperature.

Total Nitrogen Variation During Compost Process

In this experiment total N (%) variation was observed during the composting process by Kjeldhal's method (Bremner, 1965) in all seven treatments along with 15 days interval. In Poultry Manure (PM) the extent of increase of total N ranged from 0.58x - 2.68b from day 0 over day 90, Farm Yard Manure (FYM) ranged from 0.56x - 2.72b-e , Green Waste (GW) ranged from 0.59wx - 2.79b-d, PM + FYM ranged from 0.92s-x – 2.82b-d, PM + GW ranged from 0.66v-x – 2.91a-c , FYM + GW ranged from 0.79u-x – 3.07ab and PM + FYM + GW ranged from 0.93s-x - 3.36a. All treatments were significantly different, with PM+FYM+GW giving significantly higher amount of N with time span. The values are shown in Table 4.1. Previous studies revealed that composted organic materials by releasing nutrients slowly dropping the losses improve fertilizer use effectiveness, particularly Nitrogen (Nevens & Reheul, 2003). In this study during the decomposition process the N was found to be increased as the volume of compost decreased. In the mixture of composts made up of various organic wastes the 28 degree of decomposition was highest and as a result of this degradation the highest amount of total N was observed. A similar outcome was observed by (Sánchezmonedero et al. (2001) during composting process. The nutrient release was greatest at the active phase known as thermophillic phase where the temperature was maximum and thus total nitrogen attained near the maximum value (Bernal et al., 2009). There is also a strong relationship of C/N ratio and release of N contents, as the C/N ratio declines the N content increases (Chaves et al., 2005, Al- bataina et al., 2016). Khan (2012) conducted an experiment and concluded that on day 120 over day 0 the greatest release of N was noticed during composting where absorption decrease from 1.45% to 1.30% showing 10.3% losses. At early stages of composting increase in nitrogen content may be owing to the volatilization of NH4-N within the time span. Mondini et al.(1996) also concluded comparable losses of Nitrogen in PL subsequent to composting. Mary *etal*. (1996) suggested that for soil microorganisms can be a restrictive issue for the N availability because soil microbes dependable for breakdown of organic substance. Kay and Hart (1997) suggested that a microorganism converted N insufficient undergoes microbial decay when organic supplies having inclusive C: N ratio.

Table1. Variation in total nitrogen (%) contents of composts prepared from different organic wastes during 90 days of composting

Treatments	Incubation interval(Days)							Mean
	0	15	30	45	60	75	90	
PM	0.58 b	0.56 b	0.59 b	0.92XY	0.66 a	0.79 Z	0.93X	**1.76d**
FYM	0.77 Z	0.74 Z	0.86Y	1.25V	1.06 W	1.12 W	1.09 W	**1.63 e**
GW	1.51S	1.34TU	1.07 W	1.29UV	1.37 T	1.89Q	1.56S	**1.62 e**
PM+FYM	1.99P	1.74 R	1.74 R	2.14NO	1.69 R	2.27L	1.97P	**1.90b**
PM+GW	2.23LM	2.09O	2.17MN	2.43 JK	2.61H	2.38K	2.50I	**1.86 c**
FYM+GW	2.41IJ	2.23LM	2.27L	2.49IJ	2.74FG	2.83DE	2.89CD	**2.05 a**
PM+FYM+GW	2.79EF	2.72G	2.68G	2.82 E	2.91 C	3.07 B	3.36A	**2.04 a**
Mean	1.22 e	1.43 de	1.56 d	1.98 c	2.14b	2.75 a	2.84 a	
LSD	**0.0642**							**0.0243**

Concentration of Total P (%) During Composting Process

Total P (%) concentration was analyzed during the composting process. The Phosphorus increased considerably with the time duration in all the seven treatments as comparison with the preliminary day 0. The concentration of P augmented in all treatments due to the decomposition of organic matter during composting. The values are given in table 4.2. In PM the enormity of increase ranged from 0.33e - 3.87g, FYM ranged from 0.38de - 4.01e, GW ranged from 0.24f - 3.73h, PM + FYM ranged from 0.49ab - 4.45b, PM + GW ranged from 0.41cd - 4.18d, FYM + GW ranged from 0.46bc - 4.32c and PM + FYM + GW ranged from 0.52a - 4.57a that is the highest proportion among the all treatments with time span. All seven treatments showed significant differences.

Soil fertility and crop productivity are hampered by its scarcity around the world (Ochwoh et al., 2005). Keeping in view the Pakistani soils also have deficiency of P (Rashid et al., 2005) elevated price of phosphate fertilizers, enormous treasury of Rock Phosphate (RP), (PMDC 2006) in the countryside and advantageous compost special effects on crops. From 0.24% in GW to 4.57% in PM+FYM+GW, this study found a wide range of total P concentrations among composts. If carbon, hydrogen, and nitrogen are lost as CO2, H2O, and NH3, respectively, with the exit gas, but P is maintained in the sample, the increase in total P content may be the result of a concentration effect (Wei et al., 2015). As found by Raut et al. (2008), The increase in microbial biomass might be responsible for the increase in the proportion of P. It has been found that chicken manure is rich in nutrients and contains just 3.24% nitrogen, 4.26% phosphorus, and 2.54% potassium, while FYM (cow dung) contains only 1.86% nitrogen, 2.48% phosphorus, and 2.112% potassium. According to Hileman et al. (1980) to make use of organic resources in the variety of compost and FYM available phosphorus status of the soil improved. Pattanayak et al. (2001) noted that with the use of green manures the available rank of phosphorus in the soil amplified.

Table 2. Variation in total phosphorus (%) contents of composts prepared from different organic wastes during 90 days of composting

Treatments	Incubationinterval(Days)							Mean
	0	**15**	**30**	**45**	**60**	**75**	**90**	
PM	0.38de	0.89Y	1.12 W	2.05Q	3.03L	3.95F	4.01 E	**2.20 E**
FYM	0.33 e	0.67 Z	0.98X	1.96R	2.75M	3.83G	3.87G	**2.06F**
GW	0.24 f	0.49ab	0.87Y	1.59S	2.35O	3.68H	3.73H	**1.85G**
PM+FYM	0.49ab	1.18V	1.61S	2.34O	3.48I	4.40 B	4.45 B	**2.56 B**
PM+GW	0.41cd	1.02X	1.21V	2.18P	3.11K	4.16D	4.18D	**2.32D**
FYM+GW	0.46bc	1.10W	1.34 T	2.3O	3.24J	4.29 C	4.32 C	**2.44 C**
PM+FYM+GW	0.52 a	1.28Y	1.97 R	2.45N	3.69H	4.52A	4.57A	**2.71A**
Mean	0.47e	0.84 d	0.91 d	2.05 c	3.22 b	4.15 a	4.22 a	
LSD	**0.0508**							**0.0140**

Concentration of Total K (%) During Composting Process

Total Potassium was analyzed by using Eel Flame photometer (Knudsen et al., 1982). For observing total K (%) variation during compost process diversity in treatments with 15 days interval. According to the table 4.1.3 in Poultry Manure (PM) the enormity of increase ranged from 1.36n-r - 3.62a after 75 days and then there was a general decline till 90th day of composting. Similarly Farm Yard Manure (FYM), Green Waste (GW) and PM + FYM increased from 1.15 - 2.52, 1.03- 2.45 and 1.45-2.85 respectively, after 60 days and then declined. Whereas in case of PM+GW, FM+GW, PM+FM+GW increased after 90 days ranged from 1.35-1.84, 1.36-1.97 and 1.54-2.34, respectively. The treatment PM+FM+GW remained highest among all treatments. Potassium is an essential nutrient required by plants in largest amount (Mikkelsen, 2008). In this study the K values showed some infrequent behavior unlike other nutrients, and this may occur due to the leaching losses. Similar reason was determined by Tiquia et al. (2002). Likewise, Qureshi (2014) results revealed an unusual picture for K, which shows k concentration highest in poultry manure (2.13%) as compared to FYM that is (1.72%). These results were also similar with the worked done by Gachene and Kimaru, (2003). Hasanuzzaman et al. (2010). These results contrast with worked done by Shah (2001) who determined highest contents of K (2.4 %) in FYM and P (1.74 %) in PM. Sarwar et al. (2008) reported that potassium availability manipulate by adding up of acidic or acids form compound in form of compost to the soil. Research done by other scientists (Selvakumari et al. (2000) Permanent usage of FYM compost, PM compost, and green waste instead of chemical fertilizers (Singh et al., 2002) increased the soil's potassium content.

Table 3. Variation in total potassium (%) contents of composts prepared from different organic wastes during 90 days of composting

Treatments	Incubationinterval(Days)							Mean
	0	15	30	45	60	75	90	
PM	1.37V	1.50S	1.57R	2.30I	2.57F	3.66A	2.61E	**2.23B**
FYM	1.16Y	1.30W	1.41U	1.56R	2.55F	1.75P	1.80O	**1.65F**
GW	1.04Z	1.18Y	1.24X	2.31I	2.47G	1.56R	1.66Q	**1.64F**
PM+FYM	1.46T	1.56R	2.77C	2.87B	2.88B	2.68D	2.13K	**2.33A**
PM+GW	1.36V	1.36V	1.56R	2.67D	1.76P	1.78OP	1.86N	**1.76D**
FYM+GW	1.37V	1.45T	1.57R	1.66Q	1.86N	1.97M	1.99M	**1.70E**
PM+FYM+GW	1.56R	1.67Q	1.86N	1.97M	2.06L	2.17J	2.36H	**1.95C**
Mean	1.31	1.49	1.66	1.98	2.11	2.22	1.98	
HSD	**0.0334**							**0.0924**

EC Variation during Composting Process

The EC of collected soil samples were determined (1:5 sample: water ratio) For observing total EC during compost process along with 15 days interval. Over the course of all seven treatments, the EC rose dramatically from Day 0 onward. In Poultry Manure (PM) the enormity of increase ranged from 1.30-5.99 on day 0 over day 60, Farm Yard Manure (FYM) ranged from 1.27-6.64, Green Waste(GW) ranged from 1.76-5.84, PM + FYM ranged from 1.55-4.59, PM + GWranged from 1.06-4.08, FYM + GW ranged from 1.20-4.15and PM + FYM + GW ranged from 1.14-4.13, in which FYM have highest range among the all treatmentswith time span. After 60 days there was a considerable decrease in EC values. Electrical conductivity (EC) of the compost enhances which shows the accessibility of the nutrients (kanwal et al., 2011 Low EC at the start of composting in organic waste is related to insoluble salts in organic matter as the process moving on value rise owing to breakdown of components.

In proportion to the amount of microbial activity, salts are incorporated into organic matter. The findings corroborated those of Moretti et al. (2015), who showed that the final EC in compost had decreased by 58% after 120 days of composting. The observed EC trend in composting organic waste was consistent with the findings of Bertoncini et al. (2008). Leaching of compost leachate as we irrigate the composting materials also contributed to decreases in electrical conductivity value at the end of composting processes.

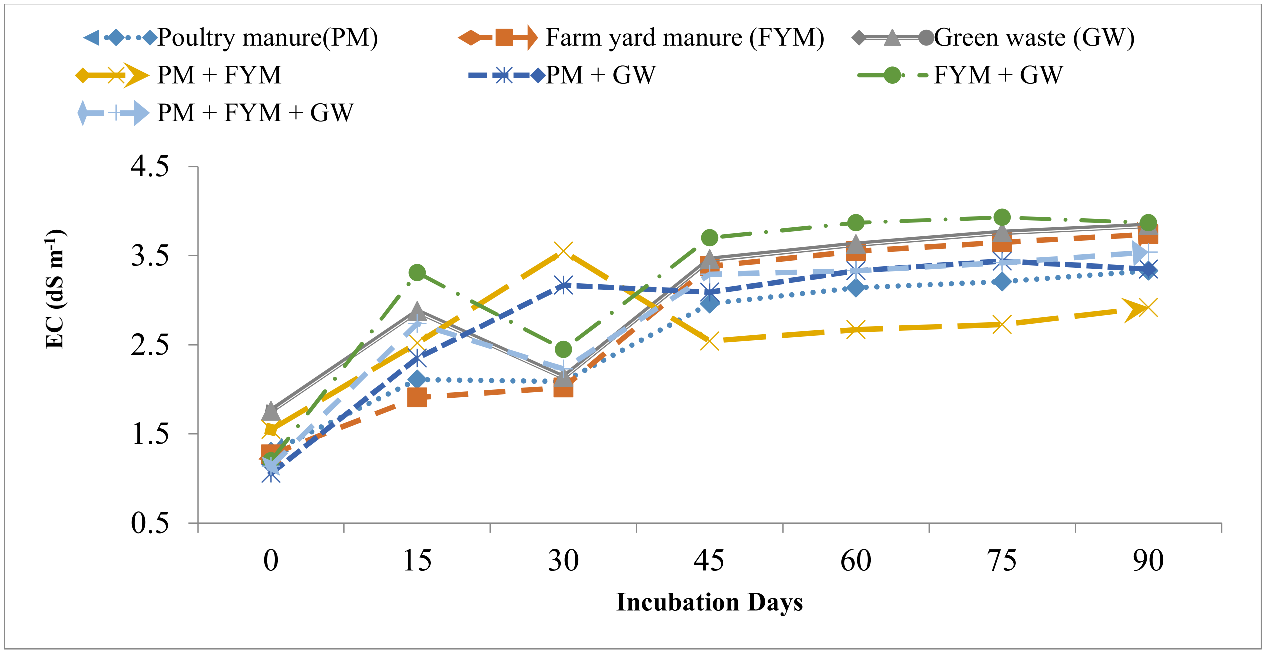


Figure 1. Variation in electrical conductivity of composts prepared from different organic wastes during 90 days of composting

CO_2 Variation during Compost Process

For observing total CO_2 emission during compost process diversity in treatments like Poultry manure (PM), Farm yard manure (FYM), Green waste (GW) and combination of PM+FYM, PM+GW, FYM+GW, PM+FYM+GW done along with 15 days interval. Unlike other GHGs emissions the CO_2 emission varied greatly throughout the experiment with the time duration in all the seven treatments as compared with the primary day 0 upto the day 90. For all the piles, CO_2 emissions were low at the start of the pile and began to increase approximately 15 days after the start of the pile. The maximum release trend was found b/w the days 30-75. Then until day 90 the values decreased. The maximum CO_2 emission (21.4431 µg kg-1 hr -1) was observed in GW, whereas the minimum value (10.96µgkg-1 hr -1) was recorded by PM + FM + GW. In this study the emission rate of CO_2 was highest among all other gases this may be due to the reason of the presence of C and most of the C converted to CO_2.Christensen et al. 2009 mentioned in his paper that carbon dioxide (CO_2) emission begins from degradation of plant's material and is believed neutral w.r.t global warming. It is also reported from different studies the origin of carbon dioxide is a microbial burning or decomposition of plant litter and SOM (Janzen, 2004; smith, 2004b). Aulakh et al. (1991) stated that apparently cultivation methods, such as provision of organic C & N to microorganism, distribution of O_2 in the soil, fluctuations in soil water contents, also have a very enormous effect on the degree and extent of CH_4, N_2O and CO_2 emissions. During composting the organic C is degraded and emitted as CO_2. All of this process is microbial assisted depending on the nature of material, degradation stage and temperature (Liang, 2003;Composting, 2000). According to (IPCC, 2023) the industrial era started in 1750 and atmospheric concentrations of greenhouse gases (GHGs) have improved significantly. For illustration, methane (CH_4)

concentration has doubled, carbon dioxide (CO_2) concentration has risen by 30% and nitrous oxide (N_2O)concentration has enhanced by about 15 %. Earth's surface emitted long-wave radiation and Greenhouse gases act to trap these radiations. The GWPs of CO_2, N_2O and CH_4 are 1, 298 and 25 correspondingly and the aptitude of each GHG to grab radiation depends on its capability to be absorbed with particular gas's and is termed (GWP) global warming potential (IPCC, 2023).

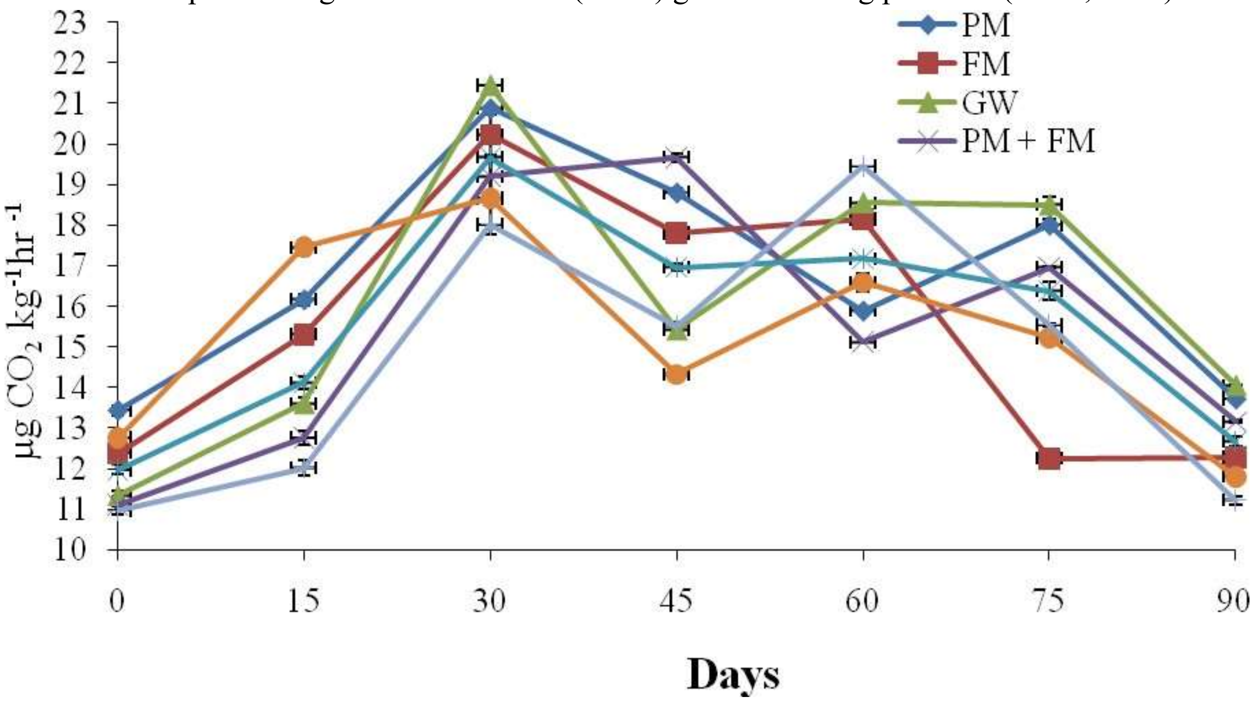


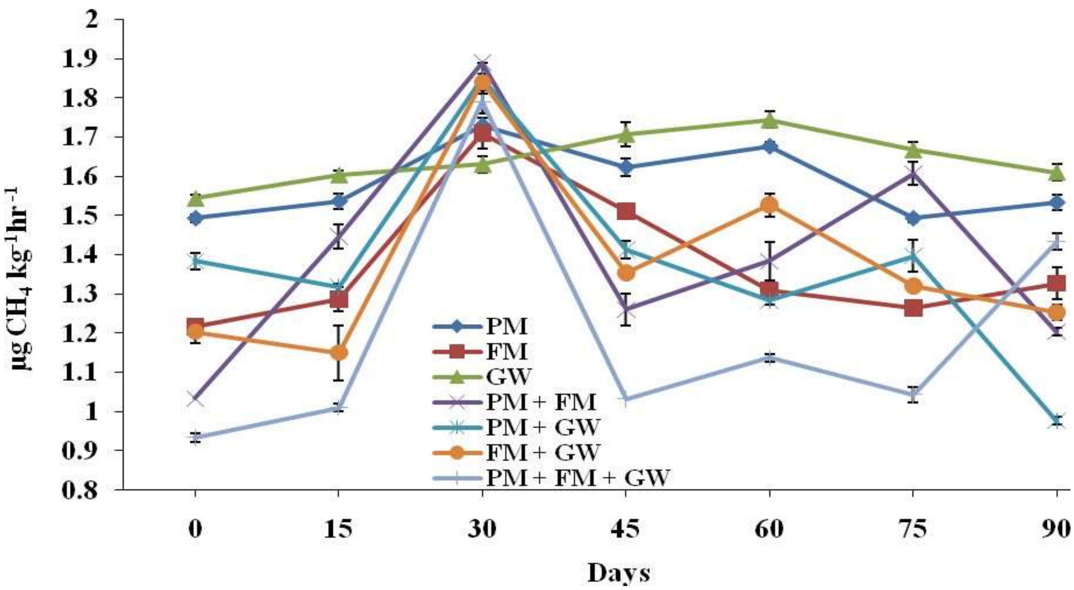
Figure 2. Emission of CO_2 from different organic wastes during 90 days of composting

CH4Variation during Compost Process

For observing total CH4 during compost process diversity in treatments like Poultry manure (PM), Farmyard manure (FYM), Green waste (GW)and combination of PM+FYM, PM+GW, FYM+GW, PM+FYM+GW done along withdays interval. The CH4increased considerably with the time duration in all theseven treatments until day 30 except GW, as it increased after 70 days because of its slow decomposition rate. Whereas in all other treatments there was a gradually decreasing the gas emission rate after 30 days until day 90.

The gas emission trend is shown in fig 4.1 In Poultry Manure (PM) the enormity of increase ranged from 1.49 -1.73on day 0 over day 30, farm yard manure (FM) ranged from 1.21-1.71, Green Waste (GW) ranged from 1.54-1.63,PM + FM ranged from 1.03 -1.89, PM + GW ranged from 1.38-1.85, FM + GW ranged from 1.20-1.84 PM + FM + GW ranged from0.93-1.79, in which PM+FM have highest range among the all treatments.

CH_4 is a significant contributor to global greenhouse gas emissions. In this study most of the CH_4 emission occurred during early stages of decomposition and then decreased as the aeration rate increased and these findings are in line with Osadaetal. (2000) and Majumdaretal.(2006). This study also revealed the highest emission in single composts as compared to mixed composts, this may bedue to the fact that mixed compost hinders the emission of C, as most of the C lost through CH_4 and CO_2(Yang, 2019). Fukumoto *et al*. (2003) also revealed that in CH_4 emission sharp peaks occur instantly after swine manure pile up, highestemissions level sustained after the first turning in the large-scale pile.



Likewise,Khan *et al*. (1997) determined that as principal greenhouse gas methane (CH_4) iswell famous from cattle production, and also **Figure 3.** Emission of CH4 from different organic wastes during 90 days of composting

Come out from composting of cattle waste. Sommer & Møller(1999) showed in his study that at some stage in composting an elevated strewing speed in swine profound litter decreases the release of CH_4. Haga et al. (1998) determined that when composting material fully-grown the mass of the anaerobic portion reputable inside the compost pile decreased and finally vanished. Within little compost pile, the span of the stage disappeared in the anaerobic portions as compared to the large compost pile. As well as Sommer (2000) reveals that during the thermo phallic phase of composting methane with high density.

N_2O Variation during Compost Process

For observing total N_2O during compost process miscellany in treatments like Poultry manure (PM), Farm yard manure (FYM), Green waste (GW) and combination of PM+FYM, PM+GW, FYM+GW, PM+FYM+GW done along with days interval. The N_2O increased considerably with the time duration in all the seven treatment as compared with the preliminary day 0 to 45 and then starts to decrease until day 90.In Poultry Manure (PM) the release of N_2O ranged from 0.026 -

0.061on day0 over day 45, Farm Yard Manure (FYM) ranged from0.0073 -0.051, Green Waste(GW) ranged from0.024 -0.068, PM + FYM ranged from0.019 -0.043, PM + GW ranged from 0.016 -0.055, FYM + GW ranged from 0.004 -0.049 and PM + FYM + GW ranged from 0.003 -0.035, in which GW have highest range among the all treatments with time span. This study shows the general increase trend of N2O at the middle stage of composting due to the increased rate of decomposition. As shown in the graph 4.2 during the days 30 to 45 the maximum release was attained. Then after this peak the values starts to fall over. Similarly, Fukumoto et al. (2003) concluded that at the middle stage of the composting N2O release started around and at that point temperature and NH_3 emissions from the compost material begin to decline. In the tiny and huge piles the emission rates of gas range between 46.5 g N_2O-N/kg T-N. Houghton et al. (1992) determined that released of Nitrous oxide (N_2O) from denitrification or nitrification process has chief role in global warming. Sommer & Moller (1999) showed that at some stage in composting an elevated strawing speed in swine profound litter decreases the release of N_2O. Osada et al. (2000) observed reduced N_2O emission rates in swine manure composting during high aeration flow rate. These studies point toward the factors that involve in the emissions of N_2O like figure and dimension of anaerobic sites in composting material. Withoutunnatural aeration through composting of livestock waste in the center of the heap, anaerobic sites are recognized owing to less air exchange instead on the surface portion of the heap, the figure and dimension of anaerobic sites in the heap on a large-scale will increase compost heap. So, he concludes that N_2O may be formed in the centre of 40 the compost heap and N_2O is produced under anaerobic circumstances. Consequently, release rates of gaseous components change by altering the level of the compost heap. Sommer (2000) concluded that in the low temperature phases emission of N_2O was important. During thermophilic phase of composting assembly of N_2O was possibly limited to the surface layers and after the temperature of the compost had drop to below 450C N_2O was produced in the center at initial level. Aulakh et al. (1991) stated that apparently cultivation methods, such as provision of organic C & N to microorganism, distribution of O_2 in the soil, fluctuations in soil water contents, also have a very enormous effect on the degree and extent of CH_4, N_2O and CO_2 emissions. As reported from different studies the origin of Carbon dioxide is a microbial decomposition or burning of plant trash and soil organic matter (Janzen 2004; smith 2004b)

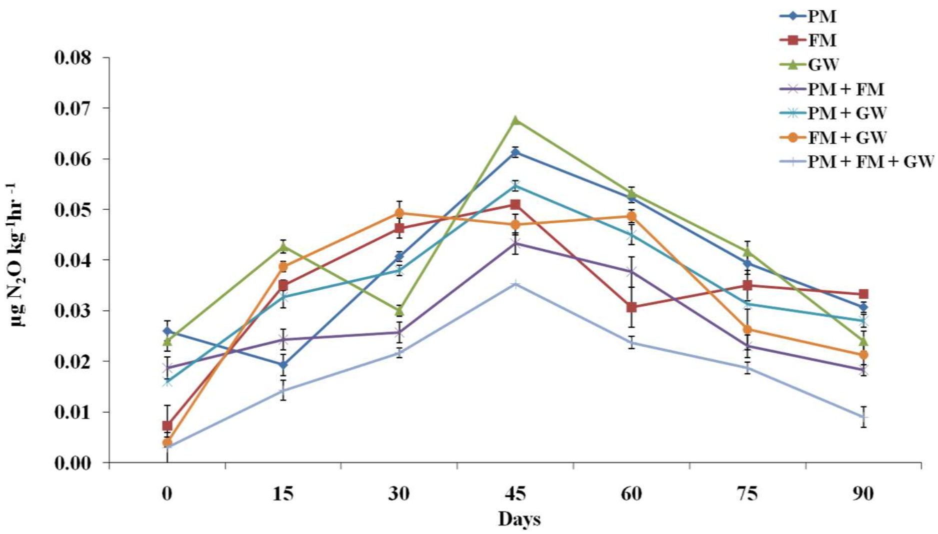


Figure 4. Emission of N_2O from different organic wastes during 90 days of composting

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