RESEARCH ARTICLE

CARBON AND NITROGEN MINERALIZATION IN SOILS AMENDED WITH MANURES AND FERTILIZERS FROM NINETEEN YEARS: A LABORATORY INCUBATION STUDY

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Abstract: Long-term manure application can alter a soil's ability to sequester nutrients and mineralize C and N. However, knowledge about the decomposition and mineralization of C and N from long-term addition of organic materials in soils is lacking. Therefore, a laboratory incubation study was carried out to evaluate the C and N mineralization in a soil to which three organic manures (15 Mg FYM or 5 Mg poultry manure or 7.5 Mg pressmud per ha^{-1}) and chemical fertilizers were applied alone or in combination. The results revealed that C mineralization rate was found to be increased with application of organic manures and amount of CO_2 evolved was further increased when organic manures were applied in combination with chemical fertilizers. Application of FYM, poultry manure and pressmud along with recommended dose of N and half of P increased the amount of CO_2 evolved by 18.1, 1.7 and 14.0 %, respectively, over application of recommended dose of N and P fertilizers. After 60 days of incubation, the highest (1868.0 mg kg^{-1}) and lowest (1055.4 mg kg^{-1}) amount of CO_2 was evolved in treatment $FYM_{15}N_{150}$ and $N_{75}P_{30}$, respectively. Among the organic manures, amount of CO_2 released followed the order: FYM>pressmud>poultry manure. Carbon mineralization increased with the progress of incubation and rate of increase was higher at initial stages and decreased gradually. Application of FYM_{15}, poultry $manure_5$, $pressmud_{7.5}$ along with recommended dose of N and half of recommended P increased nitrogen mineralization potential by 2.08, 3.22 and 12.69 % over application of recommended dose of NP fertilizers, respectively. Among the organic manures, higher N mineralization potential was observed with application of pressmud as compared to FYM or poultry manure. Application of FYM and poultry manure alone reported lower N mineralization potential as compared to recommended dose of N and P fertilizers.

Keywords: Organic manures, Fertilizers, N mineralization, CO_2 evolution

INTRODUCTION

Indian agriculture facing the problems of stagnation or even decline in production and factor productivity of major crops, deterioration of soil fertility, low diversity in production systems and increasing cost of production etc. These issues are directly related to the quantity of soil organic matter (SOM) which is a critical component of soil productivity and their maintenance is important for the long-term productivity of agro-ecosystems (Goyal *et al*., 1999). Soils of arid and semiarid regions are low in organic matter and addition of organic amendments is a suitable strategy to achieve soil recuperation in these areas (Mandal *et al*., 2007 and Bastida *et al*., 2008).

Addition of organic materials stimulates the natural soil micro-organisms and governs the biogeochemical cycles (Watts *et al*., 2010). The SOM influences soil fertility and productivity of soil as well as carbon (C) and nitrogen (N) mineralization capacities of the soil, which determines the availability of plant nutrients (Stevenson, 1994 and Fernandez *et al*., 2007). The biological decomposition of organic sources depend on the degradation rate of a wide variety of C compounds like carbohydrates, amino acids, fatty acids, lignin and nutrients present in the substrates. Thus, the amount of CO_2-C released from organic wastes in soil depends on the type of plant residues or animal manures added (Khalil *et al.*, 2005). Practices/conditions that favor higher evolution of carbon dioxide contribute to the more loss of organic matter from soil and vice-versa. A good farming practice can decrease CO_2 evolution into the atmosphere and enhance soil fertility and productivity. Increasing C sequestration in agricultural soils and making soil as a net sink for atmosphere C can be achieved by adoption of the best management practices. On other hand, present structure and output of agricultural systems could not be maintained with no applications of chemical fertilizers. Although most of the agricultural crops respond to N fertilizers applications, however, it is most difficult to manage because it is lost most readily from oxidized and reduced soil layers. The N availability for crops includes the inorganic N (NO_3^--N and NH_4^+-N) in manure and fertilizers plus the amount of organic N mineralized following application. Mineralization of N is the transformation of N from organic into inorganic form which produces NH_4^+-N and NO_3^--N, which are absorbed by plants. Therefore, mineralization governs the supply and magnitude of mineral N from soil to plants. The net production of mineral-N depends upon the outcome of the mineralization-immobilization turnover rate (Wang *et al*., 2003). The N mineralization differs for different manure types since the inorganic/organic fraction and quality of organic N varies (C/N ratio) (Anggria *et al.*,

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2012). The N supplying capacity of organic amendments in soil depends on both the initially available inorganic N present in the amendments and long term rate of mineralization of N in soil. Therefore, accurate estimation of N mineralization is essential for determining the rate of fertilizer application, optimizing NUE and minimizing adverse impacts of excessive N on the environment.

However, many of fertilization effects on the soil become apparent only in long-term field experiments. Because, continuous cropping and long-term fertilization are liable to change soil properties and crop production, depending upon the type of management practices. These experiments provide valuable information regarding the impacts of continuous application of fertilizers in varying combinations on soil health and crop productivity, which can be used for precise monitoring of changes in soil fertility, dynamics of nutrient processes and trends in crop yields.

Therefore, for efficient management of organic amendments, it is important to take into account the decomposition rate of organic amendments and their influence on N cycling processes within the soil. Considering all above aspects, the present study was carried out to evaluate the effects of long term application of fertilizers along with organic manures on C and N mineralization in soil under pearl millet-wheat cropping system.

MATERIAL AND METHOD

An ongoing long-term field experiment established during Rabi 1995 on a coarse loamy, Typic Ustochrept soil at CCS Haryana Agricultural University, Hisar (India) was selected to study the long term effects of various combinations of organic manures and fertilizers on carbon and nitrogen mineralization potential of soil. The experimental site is located at $29^o16'$N latitude and $75^o7'$E longitude in north-west part of India. The climate of the area is semi arid with a mean annual precipitation of 443 mm and mean annual temperature of 24.8^0C. The physico-chemical properties of surface soil (0-15 cm) analyzed at the start of experiment (1995) is given in Table 1. The nutrient composition of farmyard manure (FYM), poultry manure and pressmud applied in the experiment during 2013 are given in Table 2. Since 1995, the following ten treatments with randomized block design (24 m×5 m) were maintained on the permanent plots with three replications: T_1: 75 kg N +30 kg P_2O_5 ha^{-1}, T_2: 150 kg N + 60 kg P_2O_5 ha^{-1}, T_3: 15 Mg FYM ha^{-1}, T_4: 15 Mg FYM + 150 kg N ha^{-1}, T_5: 15 Mg FYM + 150 kg N + 30 kg P_2O_5 ha^{-1}, T_6: 5 Mg poultry manure ha^{-1}, T_7: 5 Mg poultry manure + 150 kg N + 30 kg P_2O_5 ha^{-1}, T_8: 7.5 Mg pressmud ha^{-1}, T_9: 7.5 Mg pressmud +75 kg N +30 kg P_2O_5 ha^{-1} and T_{10}: 7.5 Mg pressmud + 150 kg N +30 kg P_2O_5 ha^{-1}. The organic manures (FYM, poultry manure, pressmud) were applied once in a year at the time of wheat sowing. N and P were applied through urea and DAP, respectively.

Representative samples of surface soil (0-15 cm depth) were collected from field at the harvest of wheat crop in April, 2014. The samples were air dried, grounded and sieved using 2 mm sieve. 100 g soil was amended with organic manures (FYM, poultry manure and pressmud) and chemical fertilizers as per requirement of the above treatments and then incubation studies were performed to determine the C and N-mineralization. For N-mineralization, 50 g soil was incubated for 30 days at 25^0C and then soil was extracted with 2M KCl. The NH_4-N and NO_3-N in the extract was determined by Keeney and Nelson (1982) method. N mineralization potential was calculated as the difference between the final (Day 30) and initial (0 Day) mineral- N content. C mineralization was determined by periodical quantification of CO_2 evolution for 60 days following the method of Pramer and Schmidt (1964). Fifty gram air dried soil from each soil sample was placed in 500 ml Erlenrneyer flasks at field capacity. CO_2 evolved was trapped in 0.1 N NaOH and was estimated by titrating with 0.1 N HCl using phenolphthalein as indicator in presence of saturated barium chloride solution. The observation of CO_2 was measured at 3, 10, 20, 28, 37, 44, 51 and 60 days after organic manures and fertilizers application.

RESULT

Chemical properties of soil

Chemical properties of soil used in incubation study after 19 years of fertilization are presented in Table 3. The pH varied from 7.50 to 8.05 and lower values were observed where organic manures were applied as compared to chemical fertilizers. However, reverse trend was observed in case of EC and values varied from 0.33 to 0.65 dS/m and higher values were observed where FYM was applied. The OC content in soil ranged from 0.36 to 1.14 % and highest OC build up was observed in case of FYM treatments. The available N content of soil found varied from 125.5 to 193.5 kg/ha and highest content was observed with pressmud treatments. The OC content was low where chemical fertilizers was applied, however it was found in high category under organic manures (FYM @15 Mg/ha, poultry manure @5 Mg/ha and pressmud @ 7.5 Mg/ha) applied plots.

Carbon mineralization

Carbon mineralization was measured in term of CO_2 evolved due to microbial decomposition of organic matter present in soil. The results revealed that cumulative amount of CO_2 evolved varied from 1055.4 to 1868.0 mg kg^{-1} soil under different treatments (Table 4). Highest and lowest amount of CO_2 was released under the treatment $FYM_{15}N_{150}$ and $N_{75}P_{30}$ (half of recommended dose of NP fertilizers), respectively. Application of organic manures alone or in combination with chemical fertilizers significantly increased CO_2 evolution over application of fertilizers alone. Among the organic manures, whether applied alone or in combination with chemical fertilizers, highest amount of CO_2 was released with application of FYM followed by pressmud and poultry manure (Fig. 2 and 3). Application of FYM, poultry manure and pressmud along with recommended dose of N and half of P increased the amount of CO_2 evolved by 18.1, 1.7 and 14.0 %, respectively, over application of recommended dose of N and P fertilizers. Application of FYM, poultry manure and pressmud along with recommended dose of N and half of P increased the amount of CO_2 evolved by 4.9, 7.7 and 10.1 %, respectively, over application of organic manures alone. Application of recommended dose of NP fertilizers increased the amount of CO_2 released by 49.09% over application of half of recommended dose of NP fertilizers (Fig. 1).

Nitrogen mineralization potential

Total mineral N at 0 day varied from 73 to 161 kg/ha and higher amount was observed in case of pressmud treated soil, similarly total amount of mineral N at 30 day varied from 348 to 756 kg/ha under different treatment combinations (Table 5). Amount of NH_4 –N was observed higher at 0 day while the amount of NO_3 –N was higher at 30 day of incubation. Nitrogen mineralization potential varied from 273 to 595 kg ha^{-1} under different treatment combinations of organic manures and fertilizers. Highest and lowest nitrogen mineralization was obtained with pressmud$_{7.5}$N$_{150}$P$_{30}$ andN$_{75}$P$_{30}$ treatment, respectively. Application of FYM and poultry manure alone reported lower N mineralization potential as compared to recommended dose of N and P fertilizers. However, N mineralization potential was numerically higher with application of pressmud as compared to recommended dose of NP fertilizers. Among organic manures, nitrogen mineralization potential was observed in the order: pressmud> poultry manure> FYM. Application of NP fertilizers with organic manures significantly increased nitrogen mineralization potential over the application of fertilizers alone. Application of FYM$_{15}$, poultry manure$_5$, pressmud$_{7.5}$ along with recommended dose of N and half of recommended P increased nitrogen mineralization potential by 4.1, 4.4 and 11.2 %, respectively, over application of organic manures alone. Application of FYM$_{15}$, poultry manure$_5$, pressmud$_{7.5}$ along with recommended dose of N and half of recommended P increased nitrogen mineralization potential by 2.08, 3.22 and 12.69 % over application of recommended dose of NP fertilizers, respectively. Application of recommended dose of NP fertilizers increased nitrogen mineralization potential by 93.41 % over half of recommended NP fertilizers. Nitrogen mineralization potential per day varied from 9.1 to 19.9 kg ha^{-1} and highest was obtained with pressmud$_{7.5}$N$_{150}$P$_{30}$. Further it was observed that at the end of incubation period, the NO_3^--N was found to be higher than NH_4^+-N in all treatments as a result of the activity of nitrifying bacteria which converts NH_4^+-N into NO_3^--N.

DISCUSSION

Carbon mineralization

Carbon mineralization (CO_2 evolution) was found higher in organic manures applied treatments as compared to chemical fertilizers treatments. Higher CO_2 evolution in organic manure treated soil is indicative of the nutrient turn over at higher carbon expenses met through added organic carbon. This result corroborate with the findings of Li *et al.* (2011) who found that basal respiration rate in poultry litter and livestock manure treatments were higher than in NP treatments. Among organic manures applied, highest CO_2 evolution was observed with FYM application followed by pressmud and poultry manure. Increase in basal respiration with increasing organic matter content of soil could be attributed to the fact that soils receiving higher application of organics had increased levels of carbon in soil associated with increased levels of microbial biomass, microbial diversity and higher metabolic activity (Fraser *et al.*, 1988). Also FYM treatment has higher EC as compared to pressmud and poultry manure, this may also resulted into higher CO_2 evolution in FYM treatments. Yuan *et al.* (2007) and Iwai *et al.* (2012) also observed that increased salinity has positive relationship with soil respiration or qCO_2. CO_2 evolved was higher with recommended dose of NP fertilizers over half of recommended dose of NP fertilizers. Carbon dioxide evolution increased with fertilizer dose may be attributed to higher yields with fertilizers resulting in addition of higher plant residue and root biomass to the soil and it has been well documented that CO_2 evolution is a function of organic matter present in soil. Further, integrated application of manures and fertilizers showed higher CO_2 evolution than recommended dose of NP fertilizers as well as soil amended with organic manures alone. Application of integrated sources of organic manures and fertilizers provide the optimum supply of nutrients for microbial activity, which in turn resulted in greater C mineralization in soil over application of fertilizers or organic manures alone. Similar types of results were also reported by Mishra *et al.*, 2008; Kumari *et al.*, 2011; Kharche *et al.*, 2013 and Basak and Biswas, 2014).

Nitrogen mineralization potential

Nitrogen mineralization potential was affected by many factors such as soil moisture, aeration, temperature, the nature and quantity of organic matter and the nature and quantity of previous crop residues. Application of organic manure increased N mineralization potential because build up of organic matter supports increased microbial populations and activity, thereby resulting in higher N mineralization of the available substrate (Watts *et al*., 2010 and Roy and Kashem, 2014). Combined application of organic manures and fertilizers resulted in higher N mineralization over organic manures applied alone because addition of fertilizer N along with organic manures is known for stimulating mineralization and reduced immobilization (Ravankar *et al*., 2004 and Manivannan and Sriramachandrasekharan, 2009). Several studies have documented relationship between N mineralization potentials of organic materials and C:N ratio or N content of the organic materials used (Castellanos and Pratt, 1981 and Indriyati, 2014). Among the organic manures applied, highest N mineralization potential was observed with application of pressmud due to high N content and low C:N ratio. In present study, due to wide C:N ratio and high salt content of FYM, N mineralization was found to be lower than pressmud and poultry manure. This may be due to addition of higher amount of salt through FYM inhibited the nitrification process and more ammonium volatilization losses. Higher nitrogen mineralization potential was observed with chemical fertilizers application as compared to application of FYM and poultry manure alone. Ayeni, (2012) and Murugan and Swarnam (2013) also reported higher nitrogen mineralization potential with chemical fertilizers as compared to organic manures alone. This was due to the fact that application of inorganic fertilizers narrows down the C/N ratio of soil resulting in higher net N mineralization, however, due to high N content in pressmud, nitrogen mineralization potential was higher than chemical fertilizers.

Table 1. Physico-chemical properties of soil at the start of experiment- 1995

Property	**Value**
Texture	Coarse loamy
pH (1:2)	8.1
EC (dSm^{-1})	0.36
Organic carbon (%)	0.39
Available N (mg kg^{-1})	98.0
Available P (mg kg^{-1})	12.6
Available K (mg kg^{-1})	217.0

Table 2. Nutrient composition of various organic manures used

Parameter	**FYM**	**Poultry manure**	**Pressmud**
Organic carbon (%)	38.10	25.20	49.60
N (%)	1.20	2.51	3.23
P (%)	0.97	1.82	1.10
K (%)	1.87	1.72	0.86
C:N	31.75	10.04	15.40

Table 3. Some chemical properties of soil after 19 years of fertilization

Type of manure	**Dose (Mg ha^{-1})**	**Fertilizer (kg ha^{-1})**		**pH**	**EC (dSm^{-1})**	**OC (%)**	**Available N (kg/ha)**
		N	**P_2O_5**				
No manure	0	75	30	8.05	0.33	0.36	125.5
	0	150	60	8.00	0.34	0.44	132.2
FYM	15	0	0	7.68	0.60	1.02	161.5
	15	150	0	7.60	0.62	1.09	163.4
	15	150	30	7.50	0.65	1.14	166.5
Poultry manure	5	0	0	7.81	0.36	0.70	154.2
	5	150	30	7.65	0.34	0.74	160.2
Pressmud	7.5	0	0	7.77	0.35	0.81	185.2
	7.5	75	30	7.71	0.35	0.86	188.5
	7.5	150	30	7.62	0.39	0.92	193.5
C.D.(p=0.05)				**0.06**	**0.02**	**0.07**	**7.5**

Table 4. Carbon mineralization of soil amended with manures and fertilizers from nineteen years (cumulative CO_2 evolution, mg kg^{-1} soil)

Type of manure	**Dose (Mg ha^{-1})**	**Fertilizer (kg ha^{-1})**		**Amount of CO_2 evolved on different observation day(s)**							
		N	**P_2O_5**	**3**	**10**	**20**	**28**	**37**	**44**	**51**	**60**
No manure	0	75	30	50.8	155.6	304.8	452.4	612.8	768.4	915.4	1055.4
	0	150	60	67.2	229.2	522.7	797.1	1017.1	1230.5	1426.5	1573.5

FYM	15	0	0	79.9	293.9	550.9	805.1	1061.5	1297.7	1542.6	1771.6
	15	150	0	100.0	290.4	547.2	817.2	1090.6	1367.6	1622.0	1868.0
	15	150	30	106.4	299.3	558.3	826.3	1101.3	1374.3	1630.3	1858.3
Poultry manure	5	0	0	60.4	201.2	429.2	664.0	890.8	1109.8	1327.3	1486.3
	5	150	30	78.6	240.6	475.0	720.0	956.4	1182.8	1404.2	1600.9
Pressmud	7.5	0	0	74.0	249.0	494.0	749.0	986.0	1210.9	1431.5	1628.9
	7.5	75	30	78.8	259.2	509.2	769.2	1035.2	1271.2	1501.2	1722.2
	7.5	150	30	100.8	295.8	548.8	812.8	1082.8	1337.8	1577.8	1793.8
C.D. (p=0.05) Treatment= 2.37 Observation day=2.12 Treatment × Observation day= 6.72											

Table 5. N mineralization potential of soil amended with manures and fertilizers from nineteen years

Type of manure	Dose (Mg ha^{1})	Fertilizer (kg ha^{-1})		Mineral N at 0 day		Mineral N at 30 day		N mineralization potential (kg ha^{-1})	N mineralization potential (kg $ha^{-1}day^{-1}$)
		N	P_2O_5	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N		
No manure	0	75	30	91	42	182	224	273	9.1
	0	150	60	48	35	113	498	528	17.6
FYM	15	0	0	70	28	168	448	518	17.3
	15	150	0	56	30	182	434	530	17.7
	15	150	30	73	28	133	507	539	18.0
Poultry manure	5	0	0	52	28	140	462	522	17.4
	5	150	30	82	63	126	564	545	18.2
Pressmud	7.5	0	0	98	28	168	493	535	17.8
	7.5	75	30	112	42	154	563	563	18.8
	7.5	150	30	112	49	168	588	595	19.9
C.D.(p=0.05)				**3.6**	**2.1**	**4.0**	**7.5**	**8.3**	

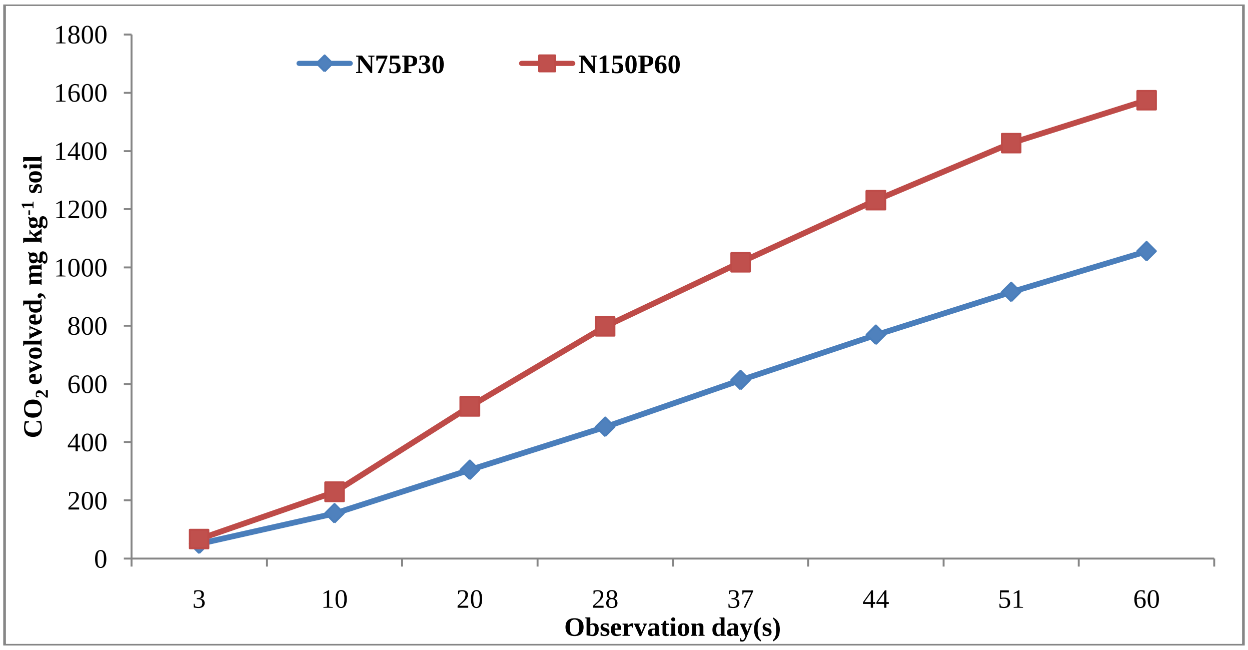

Fig.1. Amount of CO_2 evolved at different days of incubation of soil amended with half and full dose of recommended fertilizers

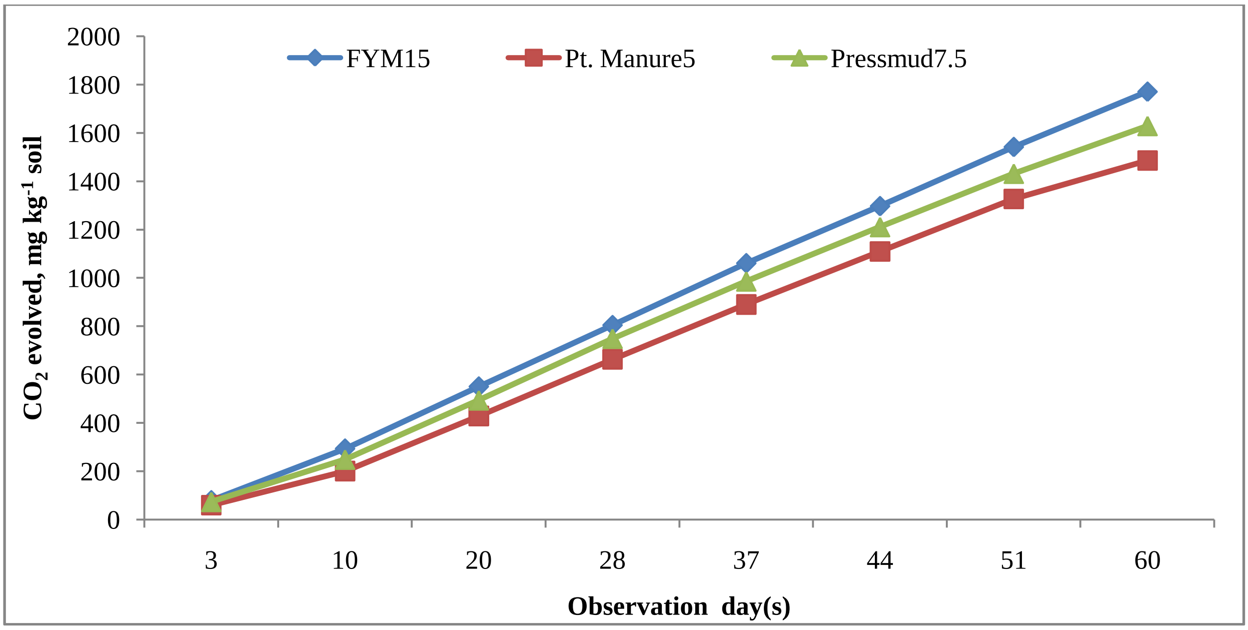

Fig.2. Amount of CO_2 evolved at different days of incubation of soil amended with different organic manures

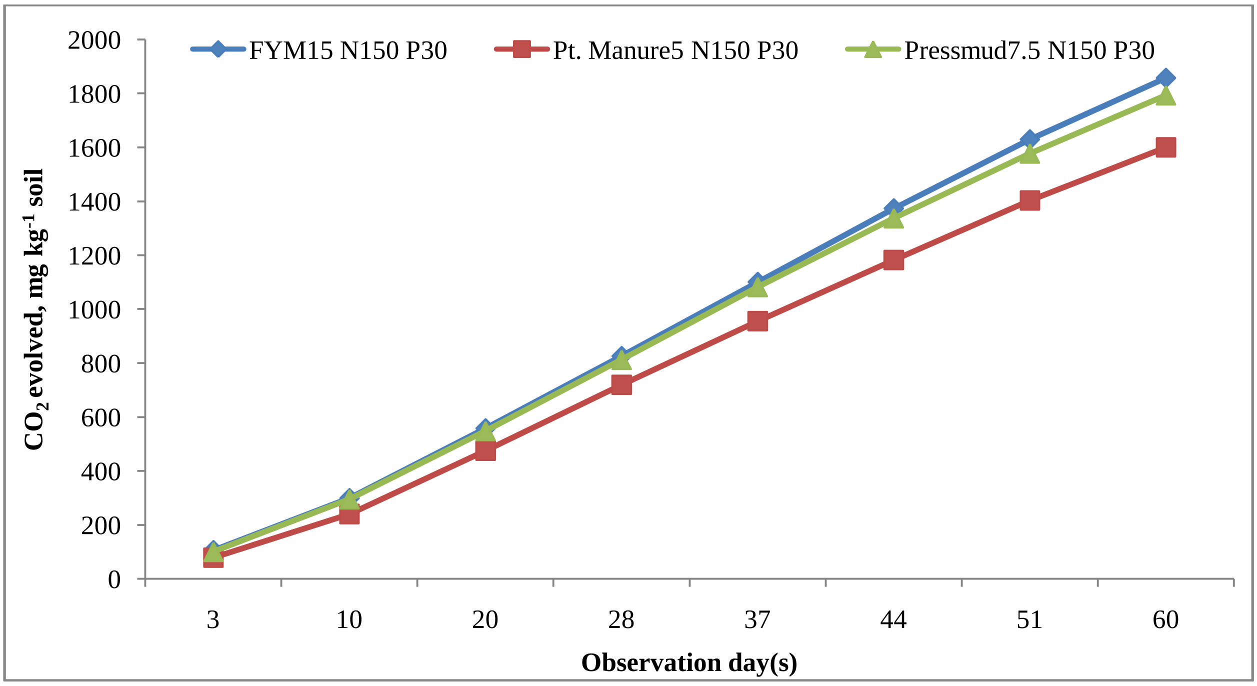

Fig 3. Amount of CO_2 evolved in soil at different days of incubation of soil amended with different organic manures in combination with chemical fertilizers

CONCLUSION

The results revealed that C mineralization rate was found to be increased with application of organic manures and amount of CO_2 evolved was further increased when organic manures were applied in combination with chemical fertilizers. Among the organic manures, amount of CO_2 released followed the order: FYM>pressmud>poultry manure. Carbon mineralization increased with the progress of incubation and rate of increase was higher at initial stages and decreased gradually thereafter. This could be attributed due to the greater C availability for microbes in FYM amended soils compared to pressmud and poultry manure dressed soils. However, among the organic manures, higher N mineralization potential was observed with application of pressmud as compared to FYM or poultry manure. Which may be due to the higher N content in pressmud itself as compared to FYM or poultry manure. Therefore, pressmud could be used as a source of N for crop production.

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