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Carbon mineralization and soil enzyme activities as influenced by green manuring crops in Entisols

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Abstract
The degradation of agricultural soils due to intensive agriculture practices is the leading cause of low organic matter, poor productivity, and diminished soil biodiversity. Entisols being minimally developed soils degrade easily though they are fertile. Entisols degrade rapidly despite being fertile. Therefore, chemical fertilizer use may not keep pace with time in soil health management for sustaining soil productivity. The most efficient way to increase natural supply of organic matter in soil is by growing and in-situ incorporation of suitable green manuring crops at the right growth stage. Better understanding of C evolution providing capability of a wide variety of green manures is important to design cost-effective and efficient C management approaches. Therefore, pot culture and incubation study was conducted for 75 days with seven treatments *viz.*, sunhemp, cluster bean, cowpea, mutant dhaincha, green gram, soybean and control and these treatments were replicated thrice. Among different green manuring crops, the incorporation of mutant dhaincha recorded significantly higher values for CO_2-C evolution throughout the incubation period. The rate of CO_2-C release was slow at the beginning followed by a sharp increase, reaching the peak rate at 45 days of incubation followed by a gradual decline thereafter in all the soils amended with green manuring crops. The green manure incorporation also improvised the enzyme activities. The rate of enzyme activity (dehydrogenase and β-glucosidase) increased rapidly during beginning to 30 days and then increased slightly till 60 days of incubation period. Among all treatments, mutant dhaincha followed by sunhemp recorded higher values for dehydrogenase and β-glucosidase activity in soil throughout the incubation period.

Keywords: Carbon mineralization, dehydrogenase, β-glucosidase, green manure crops

Introduction

Carbon is one of the most widely distributed elements on the planet. The main sources of carbon in plant and soil are plant and animal residues. The carbon enters the soil in the form of organic material and they remain in soil for years. Soil organic carbon (SOC) ultimately returns to the atmosphere as CO_2 or CH_4. SOC plays an important role as an indicator for soil health, provide plant nutrients, improve soil structural stability through aggregate formation as well as improve sufficient aeration and water infiltration capacity of soil which ultimately increase the food productivity. CO_2 respiration in soil has been utilized as a measure of relative soil fertility. The incorporation of biomass in the soil capture CO_2 through humification of OM, which follows the mineralization process, thus increasing the soil carbon content (Escalante, 2015) [1].

The depletion of soil organic matter with increased agricultural practices is the main reason for low productivity. The most efficient way to increase the natural supply of organic matter in soil is by growing and in-situ incorporation of suitable green manuring crops at the appropriate growth stage. It encourages soil microbial development and activity, which leads to plant nutrient mineralization and thus improves soil fertility and quality.

Carbon mineralization studies are essential to understand the kinetics of organic matter in the soil. The degradation of organic matter is intimately associated with the kinetics of carbon mineralization. The mineralization study of carbon (C) in agricultural residues is essential because it aids in the prediction of CO_2 releases into the atmosphere and nutrient availability to plants. The mineralization potential of organic matter in proportion to crop demands govern its efficacy as a carbon source. The release of carbon from the organic residues depends on texture, soil pH, moisture, temperature, microbial activity, and organic matter characteristics (Pathak and Sarkar, 1994) [9].

Therefore, a detailed knowledge of carbon providing capability of a wide variety of green manures is essential to design cost-effective and efficient carbon management approaches.

Given this, an investigation was undertaken to study the effect of carbon mineralization and soil enzyme activities by the influence of six green manuring crops on Entisols.

Materials and Methods

Experimental location and soil

The experiment was carried out in Division of Soil Science and Agricultural Chemistry, Pune ($18^0 32''$ N, $73^0 51''$ E) during *Rabi* 2020. The soil type selected for experiment was sandy loam. The peculiar characteristics of the soil were as follows: bulk density 1.45 g cm^{-3}, pH (1:2.5) 7.62, EC 0.14 dS m^{-1}, organic carbon 0.27%, $CaCO_3$ 4%, available N 109.8 kg ha^{-1}, available P 24.85 kg ha^{-1}, available K 257.70 kg ha^{-1}, NH_4-N 5.20 mg kg^{-1} and NO_3-N 6.15 mg kg^{-1}.

Treatment details

The seven treatments used for the experimentation were T_1 (sunhemp), T_2 (cluster bean), T_3 (cowpea), T_4 (mutant dhaincha), T_5 (green gram), T_6 (soybean) and T_7 (Control). The green manuring crops were grown in pots, harvested at 50% flowering (i.e. 45 days after sowing) and used for conducting incubation experiment.

Experiment details

The green manuring crops as per treatment were grown in respective pots without fertilizer. Recommended seed rate of green manuring crops was used for sowing on the basis of weight of soil in pot. They were harvested and incorporated at 50% flowering stage. The green manuring materials were shredded and incorporated in the same respective pots for incubation up to 75 days. The soil samples from each treatment were drawn at an interval of 30 days up to 60 days (0, 30 and 60 days) for enzyme *viz.*, dehydrogenase and β-glucosidase analysis. Incubation experiment was set up in laboratory for carbon mineralization study on the basis of soil: green yield ratio (250: 1-2). The soil samples were drawn at an interval of 15 days up to 75 days (i.e. at 0, 15, 30, 45, 60 and 75 days after incubation) and analyzed immediately for carbon mineralization (CO_2 evolution) using alkali trap method. The soil moisture content was regulated at field capacity during incubation.

Results

Effect of green manuring crop residue incorporation on carbon mineralization

Periodical Carbon Mineralization

The addition of green manure crop residues significantly increased the C mineralization rate in the soil due to the increase in the microbial population, hence soil respiration (Table 1). All crop residues exhibited a similar CO_2-C release pattern throughout the incubation, the initial slow release followed by a rapid increase till 45 days and then declined gradually (Khalil *et al.* 2005) [4]. At 45 days, high mineralization rates were observed in mutant dhaincha, (49.40 mg CO_2-C 100 g^{-1}), which was at par with sunhemp (47.26 mg CO_2-C 100 g-1) and cowpea (45.32 mg CO_2-C 100 g^{-1}) which might be due to its higher N content and narrower C:N ratio. The results obtained were in agreement with the findings of Li *et al.* (2013) [5] and Masunga and Gupta (2016) [7].

Table 1: Effect of green manuring crop residues on periodical CO_2 evolution in soil

Treatments	Periodical CO_2 evolution (mg CO_2-C 100 g^{-1})						Cumulative Total
	0 day	15 days	30 Days	45 days	60 days	75 days	
T_1: Sunhemp	18.31	25.02	32.34	47.26	35.72	25.73	184.38
T_2: Cluster bean	16.54	24.60	28.55	38.65	28.84	21.97	159.14
T_3: Cowpea	16.34	24.34	30.46	45.32	32.41	22.84	171.70
T_4: Mutant dhaincha	20.88	31.31	37.86	49.40	37.10	29.09	205.64
T_5: Green gram	17.39	23.27	29.80	38.24	27.78	20.42	156.90
T_6: Soybean	16.57	25.08	28.29	40.61	29.17	21.01	160.73
T_7: Control	11.44	11.65	11.23	11.00	10.78	11.31	67.41
SE(m)±	1.25	1.62	1.56	2.52	1.98	1.05	
CD at 5%	3.82	4.96	4.79	7.73	6.07	3.23	

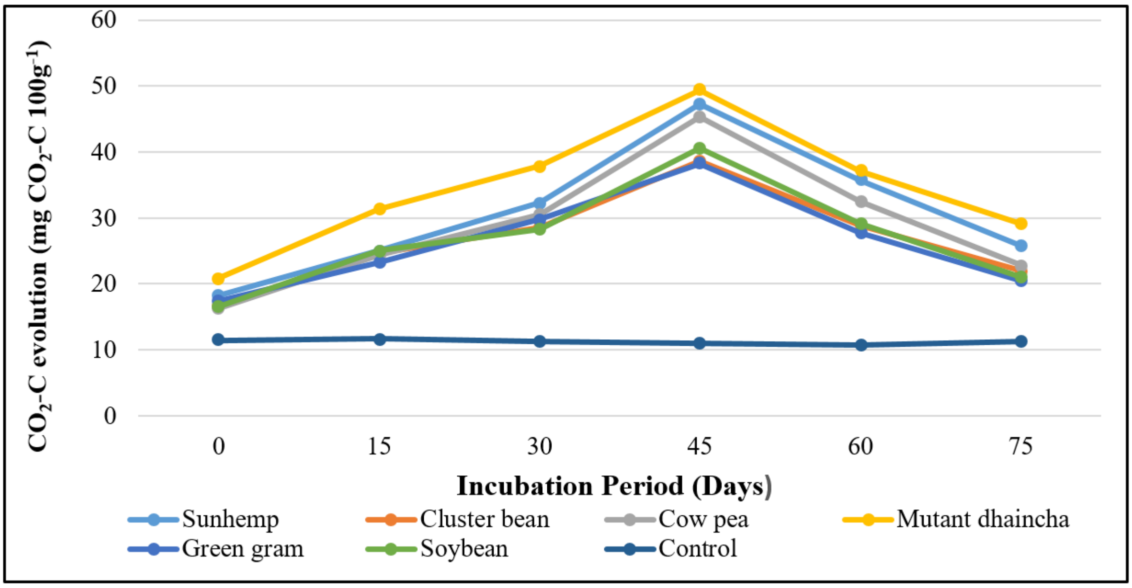

Fig 1: Effect of green manuring crop residues on periodical CO_2 evolution in soil

Cumulative Carbon Mineralization

The cumulative carbon mineralization rate was significantly higher in soils amended with green manuring crop residues as compared to unamended soil. The similar results were reported by Li *et al*. (2013) [5]. The higher rate of C mineralization was noticed in mutant dhaincha (205.64 mg CO_2-C 100 g^{-1}) which might be due to higher N content and narrower C: N ratio. The lowest CO_2-C release was noticed in green gram (38.24 mg CO_2-C 100 g^{-1}) as compared to other green manure crops.

Effect of green manuring crop residue incorporation on soil enzyme activities

Dehydrogenase Activity

The dehydrogenase enzyme is an excellent measure of microbial activity because it reflects the range of oxidative activity in soil microflora. Organic carbon released through the decomposition of added organic matter proliferated the microbial population in the soil. It resulted in the enhancement of dehydrogenase activity in soil (Table 2). All the green manure crops showed a similar enzyme activity in the soil. It increased rapidly during the initial stages of incubation to 30 days, then slightly thereafter up to 60 days. At 60 days, mutant dhaincha exhibited significantly higher dehydrogenase activity (46.80 µg TPF g-1 soil 24 hr-1) which was at par with sunhemp (46.64 µg TPF g-1 soil 24 hr-1). The high N and narrow C: N ratio of these crops cause easy decomposition of these residues. Mandal *et al.* (2007) [6] and Frankenberger and Dick (1983) [2] also obtained similar results.

Table 2: Effect of green manuring crop residues on dehydrogenase activity in soil

Treatments	Dehydrogenase (µg TPF g^{-1} soil 24 hr^{-1})		
	0 day	30 days	60 days
T_1: Sunhemp (*Crotalaria juncea*)	37.56	45.17	46.64
T_2: Cluster bean (*Cyamopsis tetragonoloba*)	31.90	36.70	38.43
T_3: Cowpea (*Vigna unguiculata*)	32.00	39.02	40.97
T_4: Mutant dhaincha (*Sesbania rostrata*)	37.70	45.52	46.80
T_5: Green gram (*Vigna radiata)*	34.65	41.41	42.83
T_6: Soybean (*Glycine max* L. Merill)	29.74	34.86	38.05
T_7: Control	20.71	21.30	21.04
SE(m)±	1.23	1.24	1.20
CD at 5%	3.77	3.81	3.67

β-Glucosidase Activity

The incorporation of different GM crop residues in soil significantly increased the β-glucosidase activity in the soil compared to control treatment (Table 3). Nayak *et al*. (2007) [8] and Utobo and Tewari (2015) [11] found that higher microbial activity and good physical conditions significantly increase β-glucosidase activity in the soil. All crop residues recorded a similar pattern of β-glucosidase activity in the soil. It recorded a significant increase initially till 30 days and then slight increase thereafter till 60 days of incubation. At 60 days, soils amended with mutant dhaincha showed significantly higher β-glucosidase activity (147.72 g PNP g^{-1} soil hr^{-1}), which was at par with sunhemp (146.61 g PNP g^{-1} soil hr^{-1}) and soybean (144.56 g PNP g^{-1} soil hr^{-1}).

Table 3: Effect of green manuring crop residues on β-glucosidase activity in soil

Treatments	β-Glucosidase (µg PNP g^{-1} soil hr^{-1})		
	0 day	30 days	60 days
T_1: Sunhemp (*Crotalaria juncea*)	136.00	145.75	146.61
T_2: Cluster bean (*Cyamopsis tetragonoloba*)	122.28	133.31	136.71
T_3: Cowpea (*Vigna unguiculata*)	132.10	138.36	140.63
T_4: Mutant dhaincha (*Sesbania rostrata*)	135.95	146.03	147.72
T_5: Green gram (*Vigna radiata*)	126.70	136.51	138.90
T_6: Soybean (*Glycine max L. Merill*)	133.51	141.96	144.56
T_7: Control (Soil)	120.83	121.08	120.42
SE(m)±	2.11	1.87	1.97
CD at 5%	6.45	5.74	6.04

Conclusion

The rate of CO_2-C release was slow at the beginning followed by a sharp increase, reaching the peak rate at 45 days of incubation followed by a gradual decline thereafter in all the soils amended with green manuring crops. Among different green manuring crops, the incorporation of mutant dhaincha recorded significantly higher values for CO_2-C evolution throughout the incubation period. The magnitude of rate of carbon mineralization followed the order: mutant dhaincha > sunhemp > cowpea > soybean > cluster bean > green gram > control. The enzyme activities like dehydrogenase and β-glucosidase of the soil were improvised significantly through green manure incorporation. The rate of enzyme activity (dehydrogenase and β-glucosidase) increased rapidly during beginning to 30 days and then increased slightly till 60 days of incubation period. Among all treatments, mutant dhaincha followed by sunhemp recorded higher values for dehydrogenase and β-glucosidase activity in soil throughout the incubation period.

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