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Effect of organic matter application and plant growth on microbial biomass carbon in three contrasting land use scenarios after rice

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ABSTRACT

When fresh organic matter enters the soil system, the soil harbours microbial activity and serves as a nucleation centre for aggregation. The addition of organic matter to soil increases microbial activity, which helps micro-aggregates to bind together to form water-stable macro-aggregates. Microbial biomass carbon was found to be significantly impacted by both organic matter application and cropping. Wheat-cropped plots trailed lentil-cropped plots in terms of microbial biomass carbon at 60, 120 and 180 DAT. Both organic matter and crop growth affected the content of microbial biomass carbon (MBC) in the soil. At higher levels of organic matter application, the largest increment in microbial biomass carbon was achieved earlier than that at lower levels of organic matter application. Among cropping treatments, lentil presented greater microbial biomass carbon than wheat, both of which had significantly higher microbial biomass carbon than fallow at sixty days following tillage and cropping. Aapplications of organic matter and cropping increased the content of microbial biomass carbon. The temporal response of organic matter application on microbial biomass carbon was found to be dependent on the rate of organic matter application. Wheat-cropped plots trailed the lentil-cropped plots in terms of microbial biomass carbon initially but the difference narrowed down towards the end of the cropping season.

Keywords: Organic matter application, microbial biomass carbon (MBC), soil aggregation, microbial activity, cropping systems

INTRODUCTION

Tillage plays an important role in moderating the soil biota and organic matter turnover in soils. This happens by the influence of tillage on infiltration capacity, aeration as well as bed for seed germination. Generally, conventional tillage is performed before each cropping season. Breakdown of aggregates during cultivation is responsible for the loss of soil organic carbon (Camberdella and Elliot, 1993; Ashagrie *et al.,* 2007; Malik *et al.*, 2021). Macro-aggregates are more sensitive to changes in land use practices and soil depth as compared to micro-aggregates and the dynamics and stability of soil aggregate formation appears to be closely linked with organic carbon stored in soils (Franzluebbers and Arshad, 1997; Nagaraja *et al.*, 2018). Soil microbial carbon or microbial biomass carbon (MBC) is the main source of labile organic carbon, thus contributing to the higher content of SOC through fresh and labile organic matter-binding groups with micro-aggregates to form macro-aggregates (Ding and Han, 2014; Guo *et al.*, 2015; Dhaliwal *et al.*, 2020). Consequently, the labile SOC fractions of aggregates may be better indicators to characterize SOC dynamics due to the larger correlation coefficient between soil aggregate-associated carbon and SOC (Chen *et al.,* 2017; Bhardwaj *et al.*, 2019). Reduced tillage with organic manure resulted in an increase in macroaggregate (>250 μm)- associated MBC (Zhao *et al.,* 2021). Reduced tillage and organic matter application over a long term significantly increase SOC concentration and active SOC fractions in the bulk soil and soil macroaggregates (>250 μm) as compared to that in conventional tillage with chemical fertilizers (Chejara *et al.*, 2021).

When fresh organic matter enters the soil system, the soil harbours microbial activity and serves as a nucleation center for aggregation (Puget *et al.,* 1995; Bhardwaj *et al.*, 2022, 2023). Free soil primary particles are cemented together into micro-aggregates (0.05 - 0.25 mm) and then into macroaggregates by persistent binding agents (e.g., clay polyvalent metal-humified organic matter complexes) induced by enhanced microbial activities. The macro-aggregates are held together by fibrous roots and poly-saccharides. These agents are relatively labile or easily decomposable and therefore macroaggregates formed during the aggregation process are less stable than micro-aggregates (Oades, 1984) and as a result more susceptible to disruptive forces induced by tillage (Tisdall and Oades, 1980, 1982). The addition of organic matter to soil increases microbial activity, which helps micro-aggregates to bind together to form water-stable macro-aggregates (Malik *et al.*, 2022). Keeping these points in mind, a study was planned with the specific objective to evaluate the effect of organic matter application and plant growth on microbial biomass carbon in three contrasting land use scenarios after rice.

MATERIALS AND METHODS

A plot on which puddled transplanted rice had been grown in the previous season was selected for the experiment.After harvesting of rice, the soil samples were drawn from the selected field before tillage. After initial soil sampling, the field was conventionally tilled twice and further pulverized with a rotavator. The experiment was then laid out in a split-plot design with 4 main plots each having 3 subplots with three replications. An organic matter source viz. vermicompost was used to apply @ 0, 5, 10 and 20 t ha^{-1} in the main plots. Two different crops namely wheat and lentil were grown in two of the subplots with one subplot remaining fallow. The soil samples from the experimental plots upto 15 cm depth were collected with a screw auger in plastic bagsand kept in the refrigerator to retard microbial activitiesat regular intervals viz. 60, 120 and 180 days after tillage and analyzed in the department of soil science and agricultural chemistry.

Soil microbial biomass carbon was measured by the chloroform fumigation extraction method (Brookes *et al.,*1985; Vance *et al.*, 1987). Before the sample was fumigated with chloroform, chloroform was made ethanol free for the best results. Fresh soil samples maintained at 4 °C were taken for the study. 10 g of soil sample was taken in three 100 ml beakers for each respective treatment, one placed in a desiccator for fumigation, second for moisture determination and third for non-fumigated carbon determination. The fumigated and non-fumigated samples added in a 250 ml conical flask were mixed with 25 ml of 0.5 M K_2SO_4 and shaken for 30 minutes on a reciprocating shaker. 10 ml of filtered aliquot was taken in a 500ml conical flask and also blank sample was taken with 10 ml distilled water instead of an aliquot and 2 ml of 0.2N $K_2Cr_20_7$, 10ml of conc. H_2SO_4 and 5 ml of ortho-phosphoric acid were added to it. The conical flasks were kept on a hot plate at 100°C for digestion for 30 mins under refluxing conditions. After digestion 250 ml of distilled water was added immediately.Then before titration 2-3 drops of diphenylamine indicator were added and titrated with 0.05 N ferrous ammonium sulphate (FAS) to detect the end point where the colour of the solution changes from dark blue to bottle green. The volume of 0.05 N FAS used in the titration was noted and used to calculate the soil microbial biomass carbon content in the soil samples.

RESULTS AND DISCUSSION

The data pertaining to the impact of organic matter application and cropping on microbial biomass carbon 60, 120, and 180 days after tillage (DAT) is presented in Table 1. Microbial biomass carbon was found to be significantly impacted by both organic matter application and cropping. In contrast, microbial biomass carbon was significantly increasing with increasing levels vermicompost at 60, 120 and 180 DAT.When compared to the wheat and lentil treatment, the fallow plot had the lowest levels of microbial biomass carbon over all time periods. Wheat-cropped plots trailed lentil-cropped plots in terms of microbial biomass carbon at 60, 120 and 180 DAT. The lentil-growing plot was on par with the wheat-growing plot during 120 DAT. The significant interaction effect was not observed at 60 DAT; but appeared in 120 and 180 DAT.

Both organic matter and crop growth affected the content of microbial biomass carbon (MBC) in the soil. At 60 DAT, vermicompost concentrations of 5, 10 and 20 t/ha led to a significant increase in MBC content by 83.57%, 190.08% and 306.13% respectively. Cropping lentil and wheat had a significant impact on MBC content, increasing it by

Table 1. Effect of various levels of organic matter application and cropping on microbial biomass carbon (µg/g) atvarious durations after tillage

Days after tillage	Microbial biomass carbon (µg/g)											
	60				120				180			
Organic manure levels/Crop	Lentil	Wheat	Fallow	Mean	Lentil	Wheat	Fallow	Mean	Lentil	Wheat	Fallow	Mean
OM_0	133.55	109.27	61.50	101.44	73.34	82.30	63.41	73.02	104.44	95.48	96.10	98.67
OM_5	289.40	174.10	103.23	188.91	126.38	184.15	171.79	160.77	173.72	132.03	133.00	146.25
OM_{10}	380.65	285.98	218.39	295.01	265.17	224.33	157.04	215.51	229.13	238.56	178.75	215.48
OM_{20}	469.43	440.50	326.02	411.98	291.29	259.34	172.54	241.06	306.87	297.66	246.11	283.55
Mean	318.26	252.46	177.29		189.05	187.53	141.19		203.54	190.93	163.49	
CD(OM)(p=0.05)		61.85				23.37				20.22		
CD (Crop)(p=0.05)		32.12				8.72				7.29		
CD (OM × C)(p=0.05)		NS				24.75				20.85		

79.51% and 42.40%, respectively. At 120 DAT, vermicompost concentrations of 5, 10 and 20 t/ha led to a significant increase in MBC content by 120.17%, 195.13% and 230.12% respectively. Cropping lentil and wheat had a significant impact on MBC content, increasing it by 33.89% and 32.82%, respectively. At 180 DAT, vermicompost concentrations of 5, 10 and 20 t/ha led to a significant increase in MBC content by 48.22%, 118.38% and 187.37% respectively. Cropping lentil and wheat had a significant impact on MBC content, increasing it by 24.45% and 16.78%, respectively.

The increase in microbial biomass carbon exhibited a direct relationship with the amount of organic matter applied. At higher levels of organic matter application, the largest increment in microbial biomass carbon was achieved earlier than that at lower levels of organic matter application. The decline in the relative amount of microbial biomass carbon too started earlier at higher levels of organic matter application. However, the lower levels of organic matter application resulted in a greater relative decline in microbial biomass carbon within 180 days of tillage and organic matter application. Among cropping treatments, lentil presented greater microbial biomass carbon than wheat, both of which had significantly higher microbial biomass carbon than fallowat sixty days following tillage and cropping. After another sixty days the microbial biomass carbon in both the crops appeared to be similar but still significantly higher than fallow. Observations further sixty days later exhibited far greater microbial biomass carbon in lentil as compared to wheat; with the fallow plot still lagging behind.

A similar result was found by Ghosh *et al*. (2018) where manure application increased microbial activity (MBC and MBC: total SOC ratio). Therelease of labile organic carbon stimulates microbial activities (Yagi *et al*., 2005). Cropping led to the development of microbial activities as explained by Wu *et a*l. (2014) where they found that fungal species induced significantly by total root length. Root and shoot biomass returned to the soil enriched the surface during the crop cycles resulting in higher MBC in soils (Inubushi and Nagano, 2017). Situ *et al*. (2022) found a similar result where concentrations of microbial biomass carbon increased most in the small macro-aggregates, followed by micro-aggregates under biochar amendment. Lentil treatment had higher MBC in bulk soils than wheat due to the tap root system of lentil crops which absorbs more nutrients and moisture from the soils. Moreover, as a leguminous crop, it fixes atmospheric nitrogen which makes lentil crop having higher MBC (Duzdemir *et al*., 2009). A similar result of higher soil MBC was reported in the leguminous crop by several researchers (Das *et al*., 2017; Majumder *et al*., 2008).

CONCLUSION

The results revealed that the application of organic matter and cropping increased the content of microbial biomass carbon. The temporal response of organic matter application on microbial biomass carbon was found to be dependent on the rate of organic matter application. Wheat-cropped plots trailed the lentil-cropped plots in terms of microbial biomass carbon initially but the difference narrowed down towards the end of the cropping season. The value of microbial biomass carbon in wheat-cropped plots was again found to be trailing the lentil-cropped plots sixty days after the harvest of the crops.

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