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Kinetics of Microbial Carbon Mineralization from Soil Incubated Agro-wastes

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Abstract: Carbon mineralization rates of various agro-wastes differ in genetic properties. Decomposition of two surface applied and incorporated crop wheat-maize residues were studied in laboratory incubation trail to determine measure the carbon mineralization with and without phosphorus addition at 23°C for 39 days. It was revealed that residue returning to arable soil increased significantly residue CO_2 evolution & emission rates were 33% higher compared to control. With incorporated residues soil emitted more CO_2-C than surfaced ones. Further, soil organic carbon levels were increased but more C was sequestered in incorporated treatments than surface applied. Microbial biomass carbon increased with addition of residues where as P application reduced it to some extent at same temperature. The total influx of CO_2-C was linearly correlated with time of incubation for both P levels and application ways under controlled environment.

Keywords: Carbon mineralization, CO_2 evolution, Soil organic carbon, Microbial biomass

1. INTRODUCTION

Depletion of soil organic carbon (SOC) is the issue in North china like rest of the world. Appropriate field crop residue management practices could replenish carbon stocks in soil for carbon sequestration soil quality and environmental health. In Guanzhong Plain abundant wheat and maize crop residues are produced after crop is harvested. Crop residues (wheat-maize) are being returned to soil after every season. Do the kinetics of C decomposition from the maize (Chen *et al.,* 2007; Hussain and Puteh, 2013) and wheat residue (Curtin *et al.,* 2008) crop residue, representing different substrate qualities, differ under field conditions. Therefore we tried to know the C mineralization kinetics of maize and wheat residues as CO_2 emission because the issue is still not well understood (Henriksen and Breland 2002).

Returning residues to the arable fields in research area has profound effect on SOC. During pulverization of the residues with soil some quantity remains on surface whereas much of it is ploughed down. Decomposition patterns of soil incorporated and surfaced substrates differ to what extent, is not completely understood. It was revealed that, organic residues carbon mixed with soil mineralized rapidly than residues applied on surface of arable fields (Wang *et al.* 2001; Curtin *et al.,* 2008). Whereas some scientists are of view that there is meager difference in C mineralization of soil mixed or surfaced residues (Wang *et al.,* 2002; Abiven and recous 2007). Curtin *et al.,* (2008) reported that decomposition of the added crop residues varies with soil application methods. So this study assessed the carbon mineralization kinetics of soil mixed and surface applied residues.

Decomposition patterns of added substrate are influenced by nutrient addition to soil due to microbial activity (Groddy *et al.,* 2004). Phosphorous (P) is major nutrient activating carbon mineralization of residue after nitrogen. Weather P addition stimulates (Cleveland *et al.,* 2002; Kaneboka *et al.,* 2004) or decreases (Teklay *et al.,* 2008) C mineralization of residues returned to soil is still misunderstood. That is why we tried to know the influence of P application on residues C mineralization kinetics. Teklay *et al.,* (2007) reported that controlled laboratory incubation offers best environment to estimate C mineralization from organic substrate that simulates well CO_2 rates measured in field. The objectives of this laboratory trail was to determine the differences in decomposition kinetics of incorporated and surface-applied wheat- maize residues with P application in laboratory incubation. To observe the impact of residue addition on soil microbial properties as SOC and biomass carbon (MBC).

2. MATERIAL AND METHODS

2.1 Experimental Site, soil and plant sample collection.

In this experiment the soil samples (0–15 cm) were obtained from, Sanyuan County, Shaanxi Province, Northwest China. Major cropping pattern is wheat and maize rotation, annually. The temperature 13.6°C are recorded, as annual means, respectively. The soil classification as Earth-cumuli-Orthic-Anthrosols with clayey loam texture. WHC of 278 g kg^{-1}, pH 7.2, organic C 8.3 g/kg, and N 0.79 g kg^{-1}. Wheat & maize residue organic carbon was 41.1% & 42.3 % and total nitrogen was 0.41% and 0.61%, respectively. The air dried soil was processed for grinding and sieving (2 mm

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sieve) and stored at 4degres for 5 consecutive days. Wheat maize residue was obtained from the field after harvesting crop. The straw was rinsed with water and oven dried at 70°C temperature. Crop residues ware chopped into pieces (< 1 cm), and subjected to incubation after thoroughly pulverizing with soil.

2.2 Treatmental design.

The experiment was conducted in Complete Randomized Design CRD with 16 treatments, replicated five times with a control. The residue ground was pulverized with soil uniformly then placed into plastic jars (13 cm, 253inner dia. mm) for an amount of 145g soil to 1.30 g wheat maize residues jar^{-1}. Potassium phosphate (K_2HPO_4) was applied as P fertilizer source to jars. Water was sprayed for maintenance of adjusted soil water contents. The plastic covered jars were transferred to incubation chamber at 23°C.

2.3 CO_2-C determination.

For absorbing CO_2 20 ml small beakers with 10 ml of one molar sodium hydroxide solution were kept on surface soil-residue mixture in jars. Jars were placed in the darkness at 23°C for incubation after covering with polyethylene sheets. Titration of sodium hydroxide was followed with 0.2 mol/L Hydrochloric acid CO_3 precipitation with Barium chloride by using phenolphthalein as indicator. All the jars were taken out and periodically opened, aerated for few minutes and soil water content was corrected and adjusted by adding distilled water. The emitted CO_2 was recorded at 3, 6, 8, 12, 15, 21, 25, 31, 35, and 39 day of during incubation period.

2.4 Deposition of carbon.

For determining organic carbon dichromate H_2SO_4-$K_2Cr_2O_7$ wet oxidation method of Walkley and Black (Nelson and Sommers, 1996) was evolved.

2.5 Soil biomass microbial carbon

It was evolved by chloroform **fumigation extraction (Vance *et al.* 1987). A 40 g moist soil sample was split into two halves then shaked at 250 rev/min with 100 ml K_2SO_4 and filtered. Organic C in 0.5 mol/L K_2SO_4 extracts was measured** by Dohrman DC 80. MBC was determined by relationship between organic carbon extracted from fumigated and subtracted from non fumigated samples.

2.6 Data analysis and interpretation. Data analysis was performed by using two way analysis of variance (ANOVA) by SPSS 16.00. Differed mean values were significant at $P < 0.05$.

Experimental set up and Incubation procedure

The laboratory research experiment was designed with 8 factorial treatments with five replicates and each 5th replication as control. The included treatments were MSI_P, MSI_0, MSS_P, and MSS_0. WSI_P, WSI_0, WSS_P, WSS_0. The treatments indicate wheat straw with and without P incorporated surface applied. In one set of treatments P was while the other without P application. Same way in one set of treatments straw was incorporated into soil in pots while in other treatment the residues thoroughly surfaced. The residue was added at the rate of 0.960 g per pot. The resides were ground then filled into plastic jars (11cm, height. 250 mm inner dia) at rate of 120 g soil & 0.961 g wheat & maize residue mixed with soil whereas other applied on soil surface in pots. For simulating field conditions the quantity of added residue to soil was 6 t DM ha^{-1}. To achieve bulk density 1.3 Mg m^{-3} soil compaction was done manually and for keeping desired moisture level 85% of field capacity distilled water was sprayed. Total weight of filled pots was noted for latter moisture content corrections. Using alkali absorption method carbon dioxide evolution was regularly collected and monitored, throughout incubation experiment**.**

3. RESULTS AND DISCUSSION

Kinetics of CO_2-C evolution

Generally, maximum CO_2-C evolution rates were observed at day 3, the rates declined, subsequently afterwards. A month later emission rates were similar to initial rates indicating that maximum residue C was mineralized. Comparatively higher CO_2-C emission rates were maintained with soil incorporated residues than surface applied. With treatment S_IWP_1 higher CO_2-C emission rates were observed. CO_2-C emission rates were enhanced with P addition at initial stage but latter remained same. **(Fig. 1).**

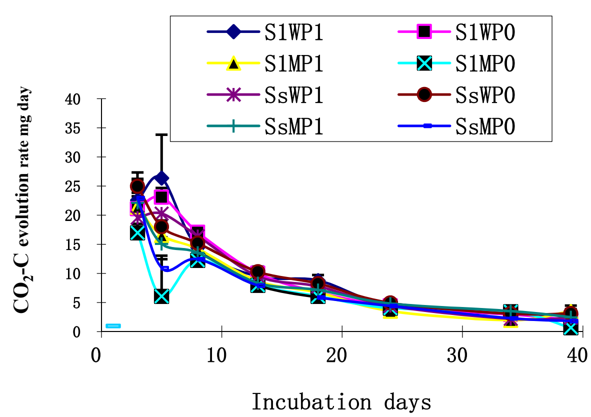


Fig. 1. Pattern of CO_2 evolution rate from the straw amended treatments at 23^{0}C in 39 incubation days.

P applied had also positive effect on the CO_2 emission maximum CO_2 was evolved in S_IWP_1 treatment. The highest CO_2-C emission was measured in treatment (S_IWP_1) followed by (S_IMP_0). Both P rates, methods of residue placement and incubation time were linearly correlated with cumulative CO_2-C. (**Table 1).**

Table 1. Cumulative CO_2-C (mg pot^{-1}) emission from incorporated and surface applied wheat and maize straw along with addition of P from all treatments.

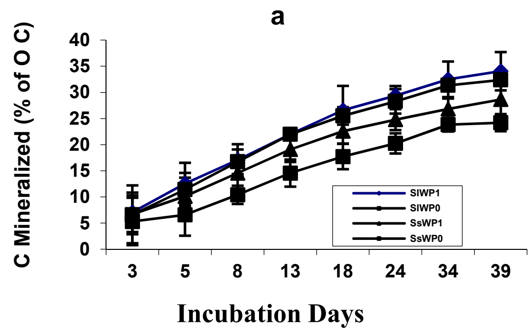
P rates	Soil placement of straw				Average
	S_IW	S_IM	S_SW	S_SM	
P_1	312.3 ±6.7 a	283.6 ±3.8 bc	257.9 ±4.3 d	279.3 ±3.1c	**283.30 A**
P_0	301.2 ±5.4 abc	309.6 ±3.3 ab	229.0 ±4.5 e	246.6±3 .2 de	**271.66 B**
Average	**306.81 A**	**296.62 A**	**243.48 B**	**263.01 B**	

*Significant difference among treatments are indicated at *$p<0.05$:* significant difference among means are indicated at $p<0.01$.

This study showed that CO_2-C evolution rates were elevated in first phase of C decomposition. The emission rates were lower after one week as organic soluble compounds were mineralized. Decline in residue C decomposition show that more residue C was sequestered in soil or incorporated into microbial cells as biomass carbon. This result was in agreement by research work done on crop residue incubation by (Wang *et al.* 2004). Owing to closer soil- residue particles and enhanced microbial activity contact the decomposition of incorporated residue was greater than surface applied, regardless of genotypic difference of residue, substrate. Pulverization of residues with soil brought obvious increase in CO_2 evolution under an incubation experiment by Chen *et al.,* 2007. Whereas (Abiven and Recous, 2007) found no significant difference in CO_2 evolution of both incorporated or surfaced residues P application also enhanced CO_2 emission from crop residues in both the set of treatments. In a study by Kaneboka *et al.,* (2004) he reported that P application enhanced residue C mineralization than the nitrogen applied. While incubating litter residues Zeng *et al.,* (2010) revealed that P application reduced CO_2 emission from soil incubated residues in incubation experiment. Whereas many research studies showed that P application enhanced (Cleveland *et al.,* 2002), reduced (Teklay *et al.,* 2007) or no influence (Groddy *et al.,* 2004) on C mineralization in soil supplied with crop residues. We observed that P application had positive effect on carbon dioxide emission from both set of treatments. Moreover, we found that on average about 33 % of residue C was mineralized to CO_2 within 39 days at 23^0C constant temperature.

Influence of residue genotypes and soil placement methods on % C mineralized

Statistical analysis revealed that in treatments 38.92% and 26.22% residue C was mineralized to CO_2 from incorporated and surface applied treatments, respectively. While on average 33% C was mineralized to CO_2 at 23^0C at constant temperature for 39 days of incubation. (**Fig. 2).** Crop residues are one of the main sources of SOC and returning residues to soils has obvious effects on soil carbon transformation and storage**.** It is revealed that adding crop residues is beneficial for soil microbes and SOC accumulation in soil for field conditions (Jin *et al.,* 2008; Chen *et al.,* 2007)**.**



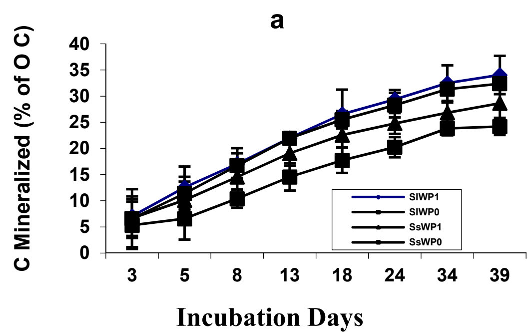


Fig. 2. The graph (a) wheat straw (b) maize straw showing % of org. carbon mineralized to CO_2 at 23^0C in 39 days of incubation.

Soil Biomass carbon accumulation

With P application S_SMP_1 treatment showed maximum microbial biomass carbon MBC was 15.24, 20.26 and 29.57% more than SIMP1, S_SMP_1, S_SWP_1, respectively. Whereas without P S_SWP_0 accumulated higher MBC that was 47.84, 107.38 and 114.58% more than S_IWP_0, S_SMP_0, S_SWP_0, respectively.

Table 2. Microbial Biomass Carbon mg kg^{-1}recorded as wheat maize residue affected by placement ways and P application.

P rates	Soil placement methods of straw				Average
	S_IW	S_IM	S_SW	S_SM	
P_1	142.0 ±7.7 b	155.6 ±3.7 b	153.2 ±4.2 b	184.1 ±6.3 ab	**158.76 B**
P_0	209.0 ±3.8 ab	149.2 ±5.8 b	309.5 ±3.6 a	144.9 ±5.4 b	**203.19 A**
Average	**175.55 A**	**152.44 A**	**231.39 A**	**164.53 A**	

- Significant difference among treatments are indicated at *$p<0.05$:* significant difference among means are indicated at $p<0.01$.

The highest value of MBC was found in maize residue surfaced treatment S_SWP_0 followed by wheat residues incorporated S_IWP_0. On average with no P applied there incorporated residues than surface applied. Returning residues also increased the SOC and MBC. There was 60% increase in accumulation of MBC in comparison with control (**Table 2).**

In our study (MBC) was not affected by residue application methods. The same was concluded by Potthoff *et al.,* (2005) who revealed MBC was enhanced after crop residues application to fields. Lou *et al.,* (2007) and Li *et al.,* (2006) showed same results in their incubation experiments that MBC significantly increased in soil with amendment of residues. Further we recorded similar results as of Teklay *et al.,* (2007) that application of phosphorus reduced MBC in all the treatments. Returning crop residues to soil plays an important role in improving soil quality, productivity and achieving sustainable utilization of soil.

4. CONCLUSION

It is concluded that residue addition to soil increased CO_2 evolution rates, and were significantly correlated with incubation time. CO_2 evolution was more rapid by

Author contribution.

Author*1 and Author*2 equally contributed. Author*3 and Author*4 assisted in soil sampling and statistical analysis of the paper formulated.

REFERENCES:

Abiven. S and S. Recous (2007). Mineralization of crop residues on the soil surface or incorporated in the soil under controlled conditions. Biol. Fertil. Soils. 43: 849-852.

Ajwa, H. H and A Tabatabai (1994). Decomposition of organic materials in soils. Biol. Fertil. Soils, 18: 175-182.

Claveland C, A. R. Townsend and S. K. Schmidt (2002). Phosphorus limitation of microbial processes in moist tropical forests: evidence from short term laboratory incubations and field studies. Ecosystems 5: 680-691.

Curtin D., F. Selles H. Wang, C. A Campbel and V. O Biederbeck (2008). Carbon dioxide emissions and transformation of soil carbon and nitrogen during wheat straw decomposition. Soil Sci. Am J 62: 1035-1041.

Chen, H., and S. K. Yakov (2007). Effect of nitrogen and intensive mixing on decomposition of C- labeled maize (Zea mays L) residue in soils of different land use types. Soil & Tillage Res. 96: 114-123.

Duong, T. T., and P. Marshner (2009). Frequent addition of wheat straw to soil enhances carbon mineralization rates. Soil Biol. Bioch. 41: 1475-1482.

Henriksen F. and N. Breland (2002). Carbon mineralization, fungal and bacterial growth and enzyme activities as affected by contact between crop residues and soil. Biol. Fert. Soil. 35: 41-48.

Hussein M. B and A. B. Puteh (2013). Emission of Carbon Dioxide Influenced by Different Water Levels from Soil incubated Organic Residues. The Scientific World J 4: 578-582.

Jin K., S. Sleutel, D. Neve S, Gabriels D. Cai and D. Hofman (2008). Nitrogen and carbon mineralization of surface-applied and incorporated winter wheat and peanut residues. Biol. Fertil. Soils. 44:661-665.

Kaneboka, J., C. Nivyza., l Sibomana (2004). Effects of nitrogen and phosphorus fertilizer addition on wheat straw C decomposition in Burundi acidic soil. Plant & Soil and Env. 7: 151–162.

Lou Y, L. X. Ren, P. Zhou, T L, Zhang and I Kazuyuki (2007). Effect of Rice Residues on Carbon Dioxide and Nitrous Oxide Emissions from a Paddy Soil of Subtropical China. Water Air Soil Pollut. 178:157-168.

Li X, G. Li, M. Qi, S Bhupinderpal, J Z Cui and Z. Rengel (2006). Decomposition of maize straw in saline soils. Biol. Fert. Soils. 42: 366-370.

Luj H, Y. Qiaojuan, L Xiangyang and H. Jinyou (2002). Straw resources and their utilization in China. Transactions of the CSAE. 18: 87-91.

Groddy. M, M. E. silver and R.C Oliveira (2004). The effect of phosphorus availability on decomposition dynamoics in seasonal lowland amzonian forest. Ecosystems. 7: 172-179.

Nelson, D. W and L. E. Sommers (1996). Total carbon, Organic carbon and organic matter. In: Spark.D. L, (ED) Methods of Soil Analysis. Part 3. Chemical Methods. Wisconsin, USA, 961-1010

Putthoff M., J. Dyckmans, H. Flessa and A. Muhs (2005). Dynamics of maize leaf straw mineralization as affected by the presence of soil and availability of nitrogen. Soil Biol. Biochem. 37:1259-1266.

Teklay T, A. Nordgren, G. Nyberg and A. Malmer (2007). Carbon mineralization of leaves from four Ethiopian agro forestry species under laboratory and field conditions. Appl. Soil Ecol. 35:193-202.

Vance E D, P. C. Brookes and D. S Jenkinsen (1987). An extraction method for measuring soil microbial carbon. Soil Biol Biochem. 19: 703-707.

Wang, H. D, Y. W. Curtin, B. G. Jame, M Conkey and H. F. Zhou (2004) Simulation of Soil Carbon Dioxide Flux during Plant Residue Decomposition. Soil Sci. Soc. Am. J. 66: 1304-1310.

Zeng. D., H. R. Mao, X. Scott and D. Yang (2010). Carbon mineralization of tree leaf litter and crop residues from poplar-based agro-forestry systems in Northeast China: A laboratory study. App Soil Ecol. 44:32-37.