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Full Length Research Paper

Decomposition characteristics of maize (*Zea mays.* L.) straw with different carbon to nitrogen (C/N) ratios under various moisture regimes

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Decomposition of maize straw incorporated into soil with various nitrogen amended carbon to nitrogen (C/N) ratios under a range of moisture was studied through a laboratory incubation trial. The experiment was set up to simulate the most suitable C/N ratio for straw carbon (C) decomposition and sequestering in the soil. The purpose of this study was to determine organic C decomposition by measuring CO_2 evolution using alkali traps. Maize straw mixed with clay loam topsoil was supplied with four initial nitrogen rates (40, 80, 160, 320 mg N/0.5 g C) using $(NH_4)_2SO_4$, to adjust its C/N ratio to 80, 40, 18 and 9. The soil moisture content was maintained at four moisture levels to achieve 60, 70, 80 and 90% of field capacity. Each of the four nitrogen rates were tested against four moisture levels, arranged in complete randomized design and incubated at 20°C for 52 days. Results reveal that decomposition rates and cumulative CO_2-C was increased by about 40% in straw amended treatments as compared to the controls. On average, about 34.56% of the added straw C was mineralized to CO_2-C. Also, there was highly significant relationship between CO_2-C emission and incubation period (R^2 = 0.98). Further, straw addition with interactive effect of nitrogen and moisture had significant relationships (*p* < 0.05) with cumulative amounts of CO_2-C, soil organic C and microbial biomass nitrogen. In conclusion, straw returning with appropriate N doses and optimum moisture can sequester and restore organic C in soil, thereby improving soil quality.

Key words: CO_2 evolution, C/N ratio, microbial biomass, moisture, straw decomposition.

INTRODUCTION

Soil organic carbon (SOC) is a key indicator of fertility and quality of the arable fields. It has crucial role in nutrient cycling, improving soil physical, chemical and biological properties, crop productivity, and reducing green house gases (GHGs) (Rivero et al., 2004; Lal, 2006; Battacharyya et al., 2010). Crop straw removal, less manure addition and other agronomic practices with low organic carbon returns to arable soils have depleted SOC contents (Dalia and Grazina, 2008; Zhang et al., 2008). Decline in SOC, is an increasing scientific issue in China (Wang et al., 2008) threatening soil quality and environmental health. In order to maintain and enhance SOC, direct returning of straw to soil and proper fertilization are believed to increase SOC stocks in agricultural soils (Petersona et al., 1998; Lal, 2004; Kandu et al., 2007).

Crop residues were traditionally used in China, including Guanzhong Plain for animal feed or fuel and returned to soil as organic manures. However, this practice of straw addition to arable fields has declined since the 1980s due to ever increasing population and indiscriminate use of inorganic fertilizers (Ju et al., 2005; Wang et al., 2008). Guanzhong Plain is an important grain production area and accounts for 19% of total land with typical semi-humid climate prone to drought, located in Shaanxi Province, Northwest China. Straw removal coupled with intensive crop cultivation and less organic carbon (C) returns, has rendered soils SOC starved (Zhang et al., 2008). A great deal of straw is produced in

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this region as with maize as the major rotatory crop, which needs valuable disposal solution. Currently, about 15% of the maize straw yielded is being directly returned to arable fields. Mean while, crop residues are frequently burned in the field, leading not only to a low resource use efficiency and land degradation, but also to increase of CO_2 and GHG emissions (Liu and Diamond, 2005). Returning maize straw directly to field with high C/N ratio as organic fertilizer amendment has challenges (Wang et al., 2000) which may restrict its decomposition. Therefore, a better strategy of crop straw utilization is urgently needed to improve soil fertility and quality with reduced CO_2 emissions.

Many biotic and abiotic factors such as moisture, temperature and nutrient addition drastically affect straw decomposition added to soil. Research shows that crop straw decomposition is greatly influenced by soil moisture (Kruse et al., 2004; Tulina et al., 2009) while others reported reduction with increasing moisture (Li et al., 2006; Iqbal et al., 2009). It is observed that nitrogen (N) addition enhances decomposition rates by reducing C/N ratios of straw added to soil (Potthoff et al., 2005; Chen et al., 2007). On the other hand, negative effects of N addition in later stages (Henriksen and Breland, 1999) have been reported also. The interactive effect of nitrogen and moisture levels on SOC mineralization is still not well understood. Most research studies have revealed the effects of either nitrogen or moisture on soil added C mineralization. However, knowledge on SOC mineralization and CO_2-C evolution from soil incorporated maize straw with N amended fixed C/N ratios under various moisture levels is still insufficient.

The present laboratory incubation study was therefore conducted to (a) evaluate influence of range of moisture levels on decomposition of maize straw C with various N amended C/N ratios by measuring CO_2-C emission incubated with soil at 20°C; (b) determine subsequent effects of returning straw on SOC and soil microbial biomass nitrogen (SMBN).

MATERIALS AND METHODS

Soil and plant samples preparation

The soil used in this incubation study was collected in August, 2009 from Sanyuan County, Guanzhong Plain area, Shaanxi Province, Northwest China. Annual winter wheat and summer maize rotation is a major cropping system in this area. The mean annual temperature and precipitation are approximately 13.6°C and 656 mm, respectively. The soils were classified as Earth-cumuli-Orthic-Anthrosols according to Chinese Soil Taxonomy (CRG-CST, 2001). The texture of soil was clay loam with field water capacity of 300 g kg^{-1}, pH 7.6, organic carbon of 9.2 g kg^{-1} and total nitrogen of 0.86 g kg^{-1}. Maize (*Zea Mays* L.) straw carbon was 42% and total nitrogen was 0.61%. Soil samples were collected from surface horizon (0 to 15 cm) using soil auger. The soil was air dried and kept in plastic bags. Visible plant residues such as roots and leaves were removed by hand. The soil was ground and sieved through 2 mm sieve and then stored for 5 days at 4°C. Maize straw (including leaves and stems) was collected from the same field after the grain was harvested and taken to the laboratory, washed with distilled water and dried at 70°C. The maize straw was cut into small pieces (<1 cm), ground and mixed with the soil samples for incubation.

Experimental design and incubation procedure

The experiment was set up using complete randomized design for 16 treatments replicated five times (each 5th replicate as control). Nitrogen was applied at four levels: 40 (N_1), 80 (N_2), 160 (N_3) and 320 (N_4) mg kg^{-1} in order to adjust C/N ratios of the maize straw to 80, 40, 18 and 9, respectively. Four moisture levels: 60%, low water (W_L); 70%, medium water (W_M); 80%, high water (W_H) and 90%, very high (W_V) of field capacity were used. Each of the four nitrogen amended C/N ratio was tested against all four moisture levels. The treatments were N_1+ W_L; N_1+ W_M; N_1+ W_H; N_1+ W_V; N_2+ W_L; N_2+ W_M; N_2+ W_H; N_2+ W_V; N_3+ W_L; N_3+ W_M; N_3+ W_H; N_3+ W_V; N_4+ W_L; N_4+ W_M; N_4+ W_H and N_4+ W_V. The ground straw was thoroughly mixed with soil, and then transferred into PVC pots (height 11 cm, inner diameter 250 mm) for an equivalent of 150 g soil to 1.25 g maize straw pot^{-1}. Nitrogen as $(NH_4)_2SO_4$ and phosphorus as KH_2PO_4 were applied to pots as water solution. Samples were slowly wetted with calculated amount of deionized water to maintain approximately designed moisture contents. The pots were then incubated at a constant temperature of 20°C for 52 days.

CO_2-C determination

25 ml vial containing 10 ml of 1 M NaOH solution were placed on soil surface inside the pot to absorb CO_2. Pots were covered with polyethylene sheets and incubated in darkness at 20°C. Excess NaOH was titrated with 0.2 M HCl after precipitating carbonates with $BaCl_2$ using phenolphthalein as indicator and subtracted from an amount titrated in control. All the pots were taken out and opened periodically, then aerated for few minutes. Soil water content was checked and adjusted by weighing and then distilled water was added, to maintain moisture levels. The CO_2 evolved was measured at 1, 2, 5, 8, 11, 14, 20, 24, 30, 36, 41 and 52nd day of incubation. At the end of incubation, soil samples were analyzed for SOC and SMBN.

Soil organic carbon

Soil organic carbon content was determined using dichromate (H_2SO_4-$K_2Cr_2O_7$) oxidation method of Walkley and Black (Nelson and Sommers, 1996).

Microbial biomass nitrogen

Fumigation extraction method was used for determining SMBN (Brookes et al., 1985). Briefly, fresh soil (equivalent to 25 g oven-dry weight) was weighed into 250 ml glass bottles. Three unfumigated samples from each treatment were immediately extracted with 100 ml 0.5 M KSO_4 on a rotary shaker at 220 rpm for 30 min and then filtered through Whatman qualitative filter paper (Chantigny et al., 2006). The remaining samples were fumigated with alcohol-free chloroform for 24 h at 25°C. Excess chloroform was removed by repeated evacuation, then the samples were extracted and filtered as described earlier. Soil filtrates were stored at 20°C prior to analysis for soil microbial biomass N. Soil microbial biomass nitrogen was calculated as:

$$SMBN = (N_{fumigated} - N_{unfumigated})/K_N$$

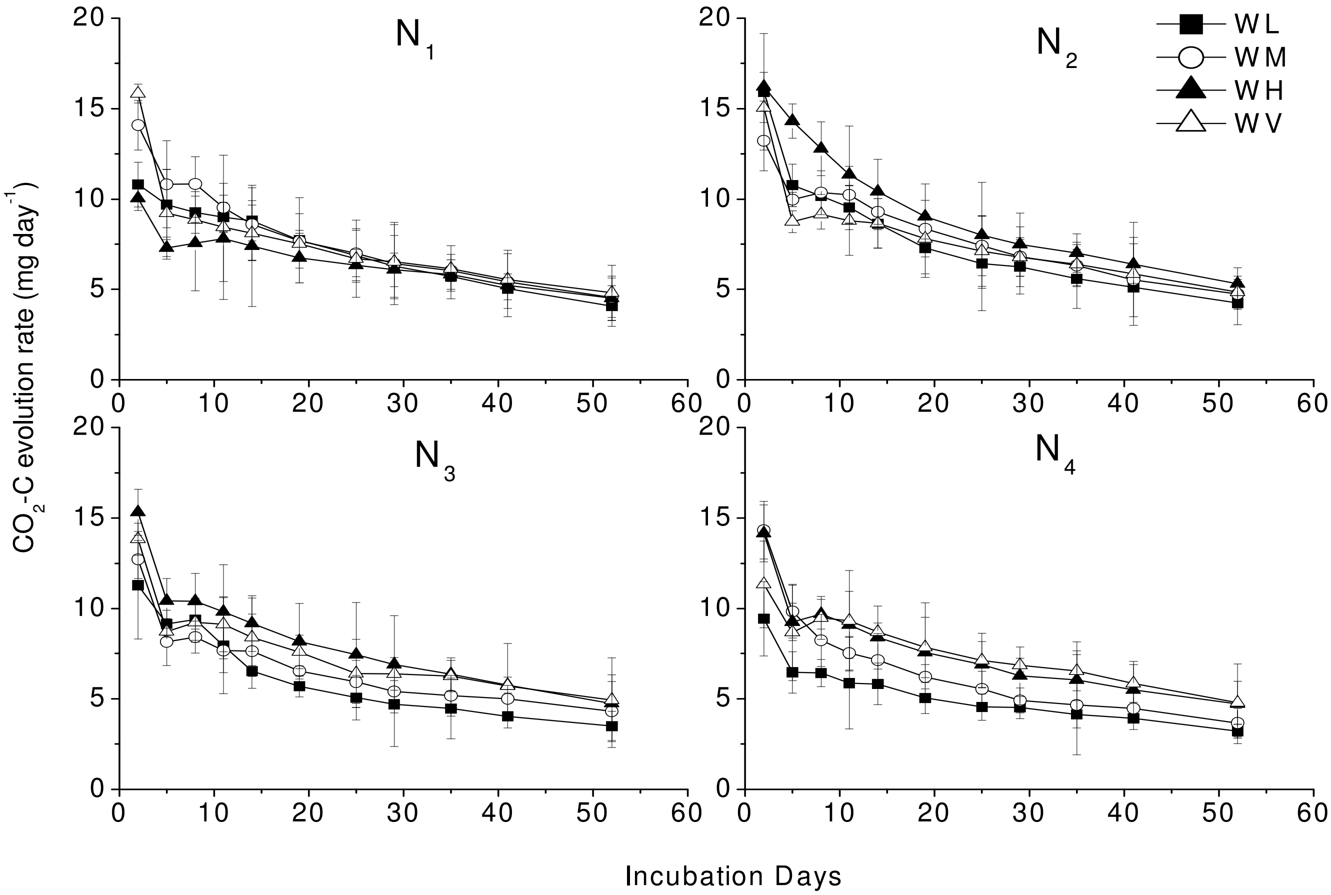

Figure 1. Emission rate of carbon dioxide from nitrogen amended treatments at different moisture levels.

Where, $N_{fumigated}$ - $N_{unfumigated}$ are the extracted fumigated and unfumigated contents of the samples and K_N is 0.54 according to Brookes et al. (1985)

Statistical analysis

Results in the table and figures are the means of four replicates expressed on an oven-dry weight basis. Data (means ± SD, n = 4) were analyzed by two-way ANOVA, and differences in means were compared by the least significant difference test at P<0.05. All statistical analyses were conducted with SPSS 16.00 (for windows) and Microsoft Excel 2003.

RESULTS

Emission rates and cumulative CO_2 production

Results revealed high, transitive and declining phases for CO_2 evolution from decomposing straw for 52 days of incubation. Rates were almost doubled in straw amended treatments as compared to control, yielding about 40% more CO_2-C affected by N and M interactions. Soil with N adjusted C/N ratios and applied moisture levels generally hastened the straw decomposition. Respiration rates from straw decomposition reached maximum levels immediately after straw addition to soil and lasted for one week. Generally, maximum CO_2-C evolution rates were observed at day 2 and remained stable to day 5 followed by a subsequent slow decline, thereafter. After 30 days, the respiration rates reduced to values close to basal levels. Comparatively higher CO_2-C emission rates were maintained for N_2 and N_3 treatment at all the four moisture levels (W_L, W_V, W_H and W_V), during the first week of incubation (Figure 1).

It was revealed that both nitrogen dose and moisture levels significantly (p<0.01) increased cumulative CO_2-C evolution in all treatments (Figure 2). The cumulative CO_2-C evolution significantly increased up to N_3 dose with all moistures applied, except N_4. The reduced cumulative evolution at N_4 dose showed that excess N could reduce CO_2 production. The highest CO_2-C emission was observed in the treatment N_3+W_V. The CO_2-C emission trend increased in the order N_1>N_2>N_3>N_4 at all moisture regimes applied. In contrast to N, all increasing moisture levels significantly increased cumulative evolution of CO_2-C. The cumulative CO_2-C emission was 1.33, 1.16 and 1.04 times higher in the W_V, W_H and M_M treatments as compared to the W_L treatment, respectively. The

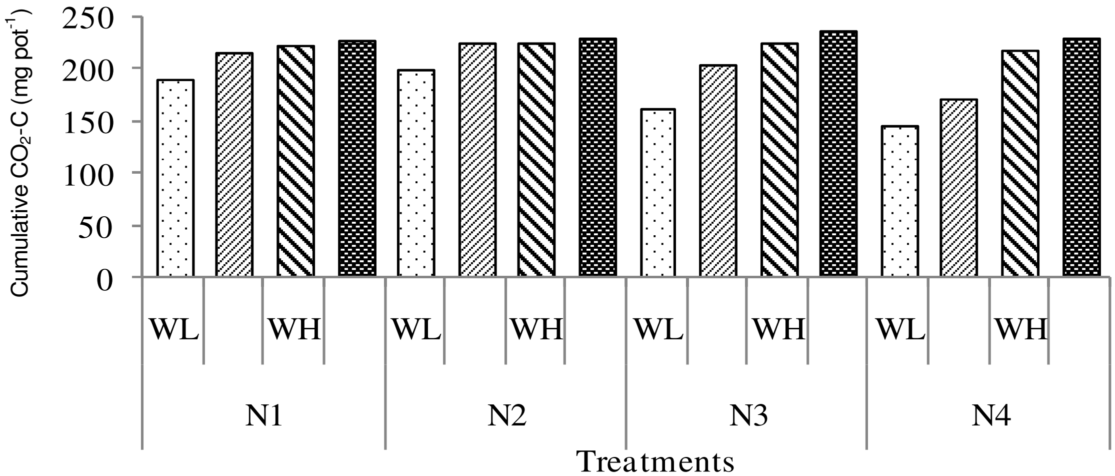

Figure 2. Cumulative CO_2 evolutions from maize straw amended and nitrogen added treatments under different moisture levels incubated at 20°C for 52 days.

increasing trend for the moisture was W_L,>$W_{M,}$>$W_{H,}$>W_V, of all N amended treatments. The cumulative CO_2-C evolution showed linear correlations with longevity of incubation time and increased with incubation periods.

Percentage of C mineralized as in organic C

The percentage of C mineralized from the decomposed straw during 52 days of incubation varied considerably and significantly ($p<0.05$) among all treatments (Table 1). Initially, C mineralization was affected from N rate 1 to 3 but declined at 4. On average, about 34.56% of added straw C was mineralized to CO_2-C incubated at 20°C for 52 days.

Soil organic carbon accumulation

SOC contents significantly ($p<0.05$) increased with incorporation of straw into soil (Table 2) while in all treatments, SOC varied significantly based on N and moisture applied. It was observed that fairly higher N doses with appropriate moistures yielded more SOC. The average value of SOC at N_3 was 2.24 g kg^{-1} followed by 2.09, 1.83 and 1.42 g kg^{-1} at N rate 1, 2 and 4, respectively. Whereas, the average values of SOC obtained for different moistures were 2.29, 1.56, 2.30 and 2.17 g kg^{-1} at W_L, W_M, W_H and W_V moisture levels.

Proportion of inorganic to organic C ratio (CO_2-C / SOC)

It was revealed that organic and inorganic (CO_2-C loss/SOC) ratio in soils amended with maize straw along with nitrogen and moisture was significantly influenced (Figure 3). The SOC/CO_2-C average ratio was 64:36 and minimum with N_3W_V (79.77:20.22) whereas maximum (51.02:48.97) was obtained for N_4W_V, respectively. Soil retaining SOC and CO_2-C was 65:35, however among them, the influence of water and N application was obvious (Figure 3).

Soil microbial biomass nitrogen

Incorporation of maize straw into soil brought significant increase in MBN along with various N dose and moisture levels applied (Table. 3). Similar trends were observed in the production of MBN as for CO_2-C evolution. It was observed that both N and M significantly affected MBN. The minimum value (26.61 mg kg^{-1}) was found in treatment N_4+W_L and maximum (35.66 mg kg^{-1}) was observed in treatment (N_4+W_L) giving an average of 29.23 mg kg^{-1}.

DISCUSSION

CO_2-C evolution rates and cumulative production

In this study, the applied mineral N increased the decomposition rate of maize straw by satisfying N requirements of decomposing microbes. CO_2-C emission rates were higher in the first week, but after day 10, it declined and results were consistent with previous work on maize straw incubation (Potthoff et al., 2005). Chen et al. (2007) incubated maize straw with soil together with N addition and found that initially rates were higher but declined after 10 days. Decrease in residue mineralization in later stages may indicate that more straw C was sequestered in soil or was incorporated into microbial biomass. Similar results were found by Henriksen and Breland (1999) in

Table 1. C mineralized as percent (% added organic C) added to all the treatments incubated at 20℃ for 52 days.

N Dose	Moisture level				Average
	W_L	W_M	W_H	W_V	
N_1	40.38 ± 0.06^{m}	40.13 ± 0.04^{n}	34.69 ± 0.13^{p}	29.09 ± 0.12^{q}	38.67 ± 3.1^{A}
N_2	43.72 ± 0.07^{k}	43.92 ± 0.11^{g}	41.94 ± 0.10^{l}	32.61 ± 0.09^{o}	38.45 ± 2.8^{A}
N_3	45.23 ± 0.04^{i}	46.22 ± 0.04^{b}	44.87 ± 0.10^{f}	43.76 ± 0.12^{h}	39.62 ± 6.3^{A}
N_4	46.74 ± 0.12^{d}	47.07 ± 0.02^{c}	44.95 ± 0.12^{a}	44.45 ± 0.12^{e}	35.63 ± 7.7^{B}
Average	35.25 ± 4.3^{C}	38.99 ± 4.5^{B}	41.07 ± 0.81^{A}	40.07 ± 0.6^{A}	

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

Table 2. Soil organic carbon (g kg^{-1}) accumulated in all treatments incubated at 20℃ for 52 days.

N Dose	Moisture level				Average
	W_L	W_M	W_H	W_V	
N_1	2.03 ± 0.5^{cd}	0.95 ± 0.2^{ghij}	2.89 ± 0.7^{ab}	2.56 ± 0.2^{de}	2.09^{B}
N_2	1.96 ± 0.4^{defg}	1.89 ± 0.5^{defg}	1.80 ± 0.5^{efgh}	1.71 ± 0.1^{efgh}	1.83^{BC}
N_3	1.80 ± 0.3^{efgh}	2.11 ± 0.3^{def}	4.43 ± 0.6^{a}	0.80 ± 0.3^{hij}	2.24^{A}
N_4	0.13 ± 0.2^{j}	1.32 ± 0.5^{fghi}	0.56 ± 0.2^{ij}	3.69 ± 0.5^{bc}	1.42^{C}
Average	2.29^{A}	1.56^{B}	2.32^{A}	2.17^{A}	

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

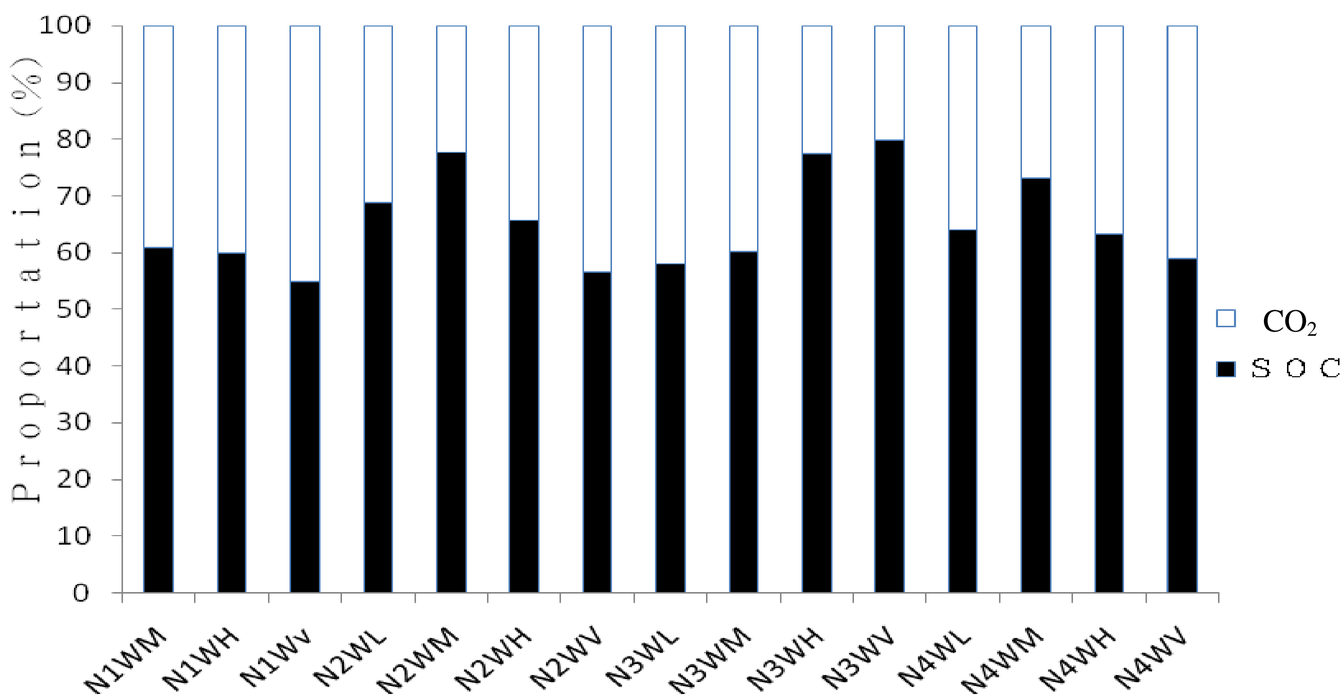

Figure 3. Proportion of organic (SOC) to inorganic carbon (CO_2-C) from all treatments incubated at 20℃ for 52 days.

their incubation study with wheat straw. The most plausible reason why decomposition efficiency increases with increasing N availability is that there is a shift in the microbial community towards organisms that are more efficient decomposers but have greater N requirements (Agren et al., 2001). Furthermore, incorporation of straw

Table 3. Soil microbial biomass nitrogen (mg kg^{-1}) accumulated in soil mixed with maize straw for all treatments incubated at 20°C for 52 days.

N Dose	Moisture level				Average
	W_L	W_M	W_H	W_V	
N_1	31.19^{defgh}	30.13^{fghi}	31.79^{efghi}	33.89^{abc}	30.75^{AB}
N_2	30.14^{bcd}	32.01^{cdef}	33.39^{bcde}	29.75^{ghi}	31.57^{AB}
N_3	35.66^{a}	30.75^{efghi}	33.10^{fghi}	32.24^{cdefg}	33.69^{A}
N_4	26.61^{i}	28.52^{hi}	31.63^{defgh}	35.30^{ab}	32.21^{B}
Average	31.65^{AB}	31.60^{C}	33.48^{BC}	32.30^{A}	

*Significant difference among treatments are indicated at p<0.05; significant difference among means are indicated at p<0.01

into soil with N adjusted C/N ratios had significant effects on maize straw decomposition rates. It was observed that rate of CO_2 evolution is a better parameter to assess decomposition process as it shows subsequent fractionation of C mineralized in specific time.

In this study, both mixing of straw together with N addition under various moistures increased CO_2-C evolution. In agreement with results found by Potthoff et al. (2005), mixing of the maize straw with soil caused almost 40% increases in the cumulative CO_2-C production than the controls. Elevated rates and cumulative CO_2-C observed at N_3 dose are as a result of C/N ratio of about 18 that favors bacterial activity with optimum water level. With N amended appropriate C/N ratio (18), more CO_2-C was evolved at N rate 3 for W_H and Wv moisture levels. Many researchers found significant relationship between decomposition of maize residue mixed with soil and with addition of mineral nitrogen (Chen et al., 2007; Potthoff et al., 2005). Decline in cumulative CO_2-C at N rate 4 suggested that N addition can only enhance CO_2-C evolution up to a certain rate, otherwise reduction will occur. At N_4, the less CO_2-C evolved could be due to luxurious consumption of N by soil microbes that suppressed CO_2-C production, or N immobilization per unit CO_2 evolved when N was in abundance.

The cumulative CO_2-C production significantly increased with increasing moisture levels (W_L>W_M>W_H>W_V) for the entire incubation experiment. CO_2 evolution was inclined towards fairly higher moisture levels; this finding may rule out negative influences of higher moisture content on microbial activity due to possible anaerobic conditions. In incubation study, Li et al. (2006) reported that during incubation of maize straw with soil under two moisture levels, there was greater CO_2-C evolution at 25% (w/w) as compared to 17% (w/w) moisture levels. It demonstrates that the increasing moisture had tendency to enhance straw decomposition as it was found in our study. Recently, Tulina et al. (2009) revealed that mineralization of wheat straw and organic matter highly depended on soil moistening in incubation studies conducted. Whereas, Iqbal et al. (2009) argued that CO_2 emission from soil incubated with straw increased from 60 to 80% moisture of field capacity and was suppressed at 100% moisture. In this study, on average, about 34.56% of maize straw C was mineralized to CO_2 within 52 days at 20°C. The higher values of carbon mineralization in this study may be due to already incorporated straw on the field along with judicious fertilization from where soil samples are drawn. However, results are consistent with the findings obtained by Abiven and Recous (2007) and Ke Jin et al. (2008) who incubated wheat and peanut residues and extent of carbon mineralized was 36 and 53% in their respective incubation studies for certain periods.

Soil organic carbon and microbial biomass N accumulation

This study revealed that SOC contents were significantly increased with incorporation of straw into soil together with various N doses and range of moisture levels applied. Highest value of SOC was obtained for the relatively higher N and moisture level applied in the treatment (N_3+W_H). This may be due to optimum C/N ratio and moisture for microbial decomposition of straw. In a study with straw and N addition, Iqbal et al. (2009) reported that N addition is the best strategy for increasing and sequestrating more straw organic carbon in the soil. Straw is one of the main sources of organic C and returning straw has obvious effects on soil carbon storage and transformation in the soil. Generally, about half of straw dry matter weight is carbon, which upon mineralization will increase SOC contents in organic matter starved soils. Chen et al. (2007) incubated maize straw with soil together with N addition and found that the SOC content was enhanced under controlled conditions. In another study, Jin et al. (2008) incubated wheat straw and reported that incorporation of crop residues in the soil is a very beneficial strategy for SOC accumulation in soil as an organic amendment. It is also revealed that a tiny change in SOC contents can cause substantial increase in the crop productivities. In a field study conducted, it was reported that with addition of 1 g kg^{-1} SOC, maize yield can be increased to about 328 kg ha^{-1} in Northwest China (Qiu et al., 2009). Therefore by enhancing SOC levels, the issue of food security and environmental quality could also be solved. Thus, straw application needs to be enhanced in long term C sequestration in soils of this region.

This study revealed that SMBN was significantly increased by incorporation of straw into soil, N addition and moisture levels. Our research findings show that returning straw to soil greatly improved soil microbial conditions. These results are in line with the results of Potthoff et al. (2005) who incubated maize straw with soil and found that straw addition significantly increased MBN. In another study, Li et al. (2006) reported that microbial properties and activity were enhanced by mixing of straw with soil. Soil microbes decompose organic residues through degradation and transformation, enhances SOM and nutrient cycling, and is a living index that reflects soil fertility and environmental quality (Spedding et al., 2004). N addition as well as moisture levels had little effect on MBN; however, straw mixing caused significant increases in MBN content. Clearly, at least in the short term, straw returned to soil can significantly increase microbial biomass. The improvement of soil microbial conditions is another important aspect to improve soil fertility by restoring C storage and improving soil quality.

Conclusion

Incorporation of maize straw into soil together with appropriate N and moisture applied had profound effects on straw decomposition rates, CO_2 evolution, C mineralization and soil parameters. The research findings show that C/N ratio of 18 and moisture level of 70 to 80% of field capacity seems to be most suitable for effective straw decomposition rates and cumulative CO_2 production. The inorganic CO_2-C to organic SOC ratio remained almost equal at relatively high N and moisture levels. This study found that addition of maize straw can significantly increase SOC and MBN contents. After the decomposition of straw, the amounts of retained carbon and carbon evolved into the atmosphere in the form of CO_2 were 64:36 proportions. By returning straw to soil, C emission from decomposition will be reduced, as one third of the carbon could be retained. Currently, the nutrient input is mainly dependent on chemical fertilizers which in long term will cause a continued decline of SOC, so returning straw will reduce the use of mineral fertilizers. Increasing SOC could greatly influence soil fertility, crop productivity and alleviation of GHGs. Therefore, application of maize straw should be promoted in the Guanzhong Plain for improving soil quality and environmental health.

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REFERENCES

Abiven S, Recous S (2007). Mineralization of crop residues on the soil surface or incorporated in the soil under controlled conditions. Biol. Fertil. Soils. DOI: 10.1007/s00374-007-0165-2. 43: 849-852.

Agren GI, Bosatta E, Magill AH (2001). Combining theory and experiment to understand effects of inorganic nitrogen on litter decomposition. Oecologia, 128: 94-98.

Bhattacharyya R, Kundu S, Srivastva AK, Gupta HS (2010). Long term effects of fertilization on carbon and nitrogen sequestration and aggregate associated carbon and nitrogen in the Indian sub-Himalayas. Nut. Cyc. Agroecosyst. 86: 1-16.

Brookes PC, Landman A, Pruden G, Jenkinson DS (1985). Chloroform fumigation and the release of soil-nitrogen a rapid direct extraction method to measure microbial biomass nitrogen in soil. Soil Biol. Biochem. 17: 837-842.

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

Chantigny MH, Angers DA, Kaiser K, Kalbitz K (2006). Extraction and characterization of dissolved organic matter. In: Carter MR, Gregorich EG (eds) Soil Sampling and Methods of Analysis. Taylor & Francis Group, LLC, Canada, pp. 617-635

Cooperative Research Group of Chinese Soil Taxonomy (CRG-CST). (2001), Sci. Press, Beijing, New York. 87

Dalia F, Grazina K (2008). The influence of soil organic carbon, moisture & temperature on soil surface CO_2 emission in the 10th year of different tillage-fertilization management. Zemderbyste-Agriculture, 4: 29-45.

Henriksen TM, Breland TA (1999). Nitrogen availability effects on carbon mineralization, fungal and bacterial growth. Soil Biol. Biochem. 31: 1121-1134.

Iqbal J, Hu R, Lin S, Bocar A, Feng M (2009). Carbon dioxide emissions from Ultisol under different land uses in mid-subtropical China. Geoderma, 152: 63-73.

Jin Ke, Sleutel S, De Neve S, Gabriels D, Cai D, Jin J, Hofman G (2008). Nitrogen and carbon mineralization of surface-applied and incorporated winter wheat and peanut residues. Biol. Fertil. Soils, DOI: 10.1007/s00374-008-0267. 544: 661-665.

Ju XT, Zhang FS, Bao XM, Romheld V, Roelcke M (2005). Utilization and management of organic wastes in Chinese agriculture: past, present and perspectives. Sci. China C. 48: 965-979.

Kruse J S, David E, Kissel M, Cabrera L (2004). Effects of drying and rewetting on carbon and nitrogen mineralization in soils and incorporated residues. Nut. Cyc. Agroecosyst. 69: 247-256.

Kundu S, Bhattacharyya R, Ghosh VP, Gupta HS (2007). Carbon sequestration and relationship between carbon addition and storage under rainfed soybean-wheat rotation in a sandy loam soil of the Indian Himalayas. Soil Till. Res. 92: 87-95.

Lal R (2004). Is crop residue a waste? J. Soil Water Conserv. 59: 136-139.

Lal R (2004). Soil carbon sequestration impacts on global climate change and food security. Science, 304: 1623-1627

Liu JG, Diamond J (2005). China's environment in a globalizing world. Nature, 435: 1179-1186.

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

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

Petersona GA, Halvorsonb AD, Havlinc JL, Jonesd OR, Lyone DJ, Tanakab DL (1998). Reduced tillage and increasing cropping intensity in the Great Plains conserves soil C. Soil Till. Res. 47: 207-218.

Potthoff Martin, Dyckmans J, Flessa H, Muhs A (2005). Dynamics of maize leaf straw mineralization as affected by the presence of soil and availability of nitrogen. Soil Biol. Biochem. DOI: 10.1016/j.soilbio.2004.11.022. 37:1259-1266.

Qiu JJ, Wang LG, Li H (2009). Modeling the impacts of soil organic carbon content of croplands on crop yields in China. Chinese J. Agric. Sci. DOI: 10.1016/S1671-2927(08)60233-3. 42: 154-161.

Rivero C, Chirenje T, Ma LQ, Martinez G (2004). Influence of compost on soil organic matter quality under tropical conditions. Geoderma. DOI: 10.1016/j.geoderma.2004.03.002. 123: 355-361.

Spedding TA, Hamel C, Mehuys G, Madramootoo CA (2004). Soil microbial dynamics in maize growing soil under different tillage and residue management systems. Soil Biol. Biochem. DOI: 10.1016/j.soilbio.2003.10.026. 36: 499-512.

Tulina AS, Semenov VM, Rozanova LN, Kuznetsova TV, Semenova NA (2009). Influence of moisture on the stability of soil organic matter and plant residues. Euras. Soil Sci. DOI: 10.1134/S1064229309110064. 42: 1241-1248.

Wang LG, Qiu JJ, Tang HJ, Hu L, Li CS, Eric VR (2008). Modeling soil organic carbon dynamics in the major agricultural regions of China. Geoderma, 147: 47-55.

Wang XB, Cai DX, Zhang JQ, Gao K (2000). Effects of corn stover incorporated in dry farmland on soil fertility [J]. Sci. Agric. Sinica, 33(4): 54-61.

Zhang QZ, Yang ZL, Wu WL (2008). Role of crop residue management in sustainable agricultural development in the North China Plain. J. Sust. Agric. DOI: 10.1080/10440040802121502. 32: 137-148.

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