

EVALUATION OF THE EFFECTS OF INOCULATED WHEAT STRAW ON SOIL ORGANIC CARBON AND CHEMICAL PROPERTIES

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ABSTRACT

Inoculation of plant residues using cultured microbial compounds has been thought to increase the rate of decomposition in soil although evidence of the efficacy of these compounds is limited. To examine the potential of inoculated wheat straw on soil properties, three industrially produced microbial inoculants (Renyuan Shengwu(RW), Taigu Bio (TB) and Green Health (GH)) were tested using laboratory incubation experiments. Inoculation rate was based on manufacturers' recommendation using mixed (I) or layered soil and straw (L) placement method. Inoculation did not significantly increase cumulative CO₂ evolution except for RW. Mixed soil-straw induced initial higher CO₂ evolution compared to the layered approach. Straw amendment increased DOC over the control up to 291%. All straw treatments increased dissolved organic carbon (DOC), total N, nitrate nitrogen (NO₃⁻-N), DTPA extractable zinc and manganese, but reduced available iron and copper. Positive significant correlation ($p < 0.01$) was recorded for total soil respiration and DOC (0.89), microbial biomass carbon (0.58), total organic carbon (0.74), total N (0.87), Mn (0.92) and zinc (0.46) while the relationship was negative for iron (-0.57) and not significant for copper (-0.19). The results predict a positive effect of straw inoculation on wheat straw decomposition as well as most of the measured soil properties without significant increase in CO₂ emission.

Key words: straw inoculation, composite microbial compounds, soil micronutrients, dissolved organic carbon, CO₂-C emission

INTRODUCTION

Incorporation of straw into soil is generally considered to be of benefit to soil organic matter (SOM). Despite the advantages of returning straw to the field, the presence of about 60% cellulose and hemicellulose (Halsall and Gibson, 1986) as well as lignin and high carbon to nitrogen ratio (Wang and Bakken, 1997; Li et al., 2012) slows down its decomposition rate compared to other crop residues. This innate characteristic is posing a limitation to maximize the use of straw in agricultural soils because of interference with

seeding of immediate crop following cereal harvest.

Many countries around the globe including China generate huge amount of wheat straw which are return to field annually (Cai and Alimujiang, 2009). However, the prolonged decomposition rate puts pressure on subsequent field cultivation, which has resulted in some farmers resorting to straw burning (Abdulla, 2007; Bhattacharyya et al., 2010; Abroet al., 2011). Straw burning has negative effect on the environment by increasing greenhouse gases (GHGs)

emission and loss of valuable plant nutrients. Many farmers are now using industrially produced lignocellulose degrading microbial compounds to increase the rate of straw decomposition (Li et al., 2012), but they are doing so without a research-based knowledge of the long-term impacts on soil quality and the environment.

Complex microbial communities are required for enhanced degradation of straw (Guo et al., 2008; Zhao et al., 2014). Soil aerobic fungi, such as *Trichoderma* and *Penicillium* spp have been identified as being involved in cellulose decomposition (Harper and Lynch, 1984). Although effort has been made to study the effectiveness of composite microbial biomass on lignocellulotic materials used as bioenergy (Guo et al., 2008; Li et al., 2012; Zhao et al., 2014), the study of their effect as direct inoculants on straw returned to agricultural field is very limited. Also, little is known about their effects on soil chemical and biological properties, especially labile organic carbon pool and soil micronutrients availability.

The four micronutrients considered essential in the most soils include iron (Fe), copper (Cu), zinc (Zn) and manganese (Mn). Their importance is associated with the ease of loss in the soil leading to deficiency and non-availability to crops. These four soil micronutrients (Fe, Cu, Zn and Mn) play important roles in crop production, and their availability can be affected by various soil management operations such as plant residue incorporation. Decomposition of crop residues releases organic compounds that can

react with micronutrients through various processes including fixation, adsorption, chelation and ion exchange (Tahir, 1984), thus influencing their concentration and availability in soils. Low available micronutrients in soil could lead to poor plant uptake resulting in deficient micronutrient diet and its related problems (Rengel, 2015).

Therefore, the aim of this research is to evaluate the effects of inoculation of wheat straw with cellulose degrading microbial compounds and straw placement method on the decomposition of wheat straw, soil organic carbon and soil nutrients.

MATERIALS AND METHODS

Sampling

Soil for the incubation study was collected from 0-20 cm layer at the Experimental Farm of Northwest A&F University, Yangling, Shaanxi Province, China. The soil class is Eum-Orthic Anthrosols (a Udic Haplustalf in the U.S. soil taxonomy). The local climate is semi-humid and prone to drought, with an average annual temperature and rainfall of 12.9°C and 620 mm, respectively. Table 1 shows the properties of the soil used in this experiment. The soil and straw required for the study were both collected from the same field after wheat harvest. The soil was air-dried and screened with 2mm sieve. The wheat straw was obtained from the same field following wheat harvest. After air-drying, the straw was chopped into pieces of <1 cm and stored dry until required for the experiment.

Table 1: Initial soil properties

Soil prop erty	p H	TO C (g/ kg)	Tot al N (g/ kg)	Avail able P	Avail able K (mg/k g)	Avail able Fe (mg/k g)	Avail able Cu (mg/k g)	Avail able Zn (mg/k g)	Avail able Mn (mg/k g)	CaC O3 (g/k g)	DT PA- Zn	To tal Zn
Valu e	7.94	14.4	4.4	12.36	166	3.22	0.56	0.4	8.96	65.1	0.74	69.8

2.2 Incubation procedure

Three commercially produced microbial products consisting of combination of different fungi and bacteria strains were used. The products were:

- Renyuanshengwu (RW): this consists of bacterium, Filamentous fungus and Saccharomycetes strain produced by RenyuanShengwu company.
- Taigubio (TB): comprises of Bacillus subtilis, Aspergillus oryzae and Trichoderma harzianum; produced by Taigubio company.
- China Green Health (GH): comprises of a bacteria strain belonging to Bacillus, Trichoderma viride and Saccharomycetes.

The experiment which consisted of nine treatments (Table 2) was replicated four times to give 36 experimental units, which were then arranged in completely randomized design (CRD). This experiment uses two straw placement methods (incorporation and layered). In layered pots, 279 g soil and 11.4 g wheat straw was arranged to three layers of soil at the depth of 1 cm each and was alternated with two layers of straw to the

depth of 5 cm each to form straw-soil layered treatments. For straw incorporation, the same amount of soil and straw used in layered treatments was thoroughly mixed together in the incubation pots. To each pot, corresponding microbial product was applied according to the recommendation of the company. TB and GH was applied at the rate of 53 kg/ha assuming 5300 kg straw was returned to the soil while RW recommended 530 kg /ha at the same straw rate. The C:N ratio of the straw was corrected to 28 using urea which was applied as water solution while non amended soil received an equivalent amount of deionised water. The water was applied at 80% of the field capacity.

Alkali trap method was used to measure the amount of CO₂ evolution. To trap the evolved CO₂, 20 ml of 2M NaOH was fixed to each pot, covered with nylon sheet and incubated at 25⁰C for 61 days. CO₂ determination was carried out on day 2, 3, 4, 5, 7, 8, 10, 12, 14, 16, 18, 20, 24, 26, 28, 31, 35, 39, 43, 50 and 61 days after incubation. Pots were opened for about 5 minutes on each determination day to allow proper aeration while NaOH vials were

simultaneously changed. The amount of CO₂ absorbed was determined by titration of NaOH against 1M HCl after precipitating with excess (40ml) 0.5M BaCl₂. The amount of CO₂ (in mg/pot) was calculated by determining the mole concentration of CO₂ trapped in each pot and convert it to weight by multiplying the mole by the molar mass.

At the completion of the incubation, the soil was divided into two; one part was kept moist in a polyethylene bag at temperature of 4°C and used to determine microbial biomass carbon while the other part was air-dried. Each part of the soil was sieved to remove un-decomposed straw before the commencement of the soil analyses.

Table 2: Treatmenttable

Number	Treatment name	Description
1	NT (control)	untreated soil
2	WSI	incorporated with wheat straw only
3	WSL	wheat straw and soil only arranged in layers
4	RWI	wheat straw incorporated soil + renyuanshengwu
5	RWL	wheat straw and soil arranged in layers + renyuanshengwu
6	TBI	wheat straw incorporated soil + Taigubio
7	TBL	wheat straw and soil arranged in layers + Taigubio
8	GHI	wheat straw incorporated soil + China Green Health
9	GHL	wheat straw and soil arranged in layers + China Green Health

Analytical procedures

Soil microbial carbon was determined by fumigation extraction procedure (Brookes et al., 1985; Vance et al., 1987). Dissolved organic carbon was determined as fraction of soil carbon extractable by 0.5 M K₂SO₄. 50 ml K₂SO₄ was added to 10g moist soil and oscillated for 30 minutes at 300 rev/min and filtered. The C concentration of the filtrate was determined using an auto analyzer. Total organic carbon was by wet oxidation method (Walkley and Black, 1934). Total N was determined using Kjeldahl digestion follow by automated titration against H₂SO₄ after which total N was calculated (Jackson,

1967). Available phosphorus was estimated following method of Olsen et al (1954). Inorganic NO₃⁻-N and NH₄⁺-N were determined as 0.5 M K₂SO₄ extractable N and their concentration were determined using automated chemistry analyzer at 545 and 660 nm, respectively. Available Fe, Cu, Zn and Mn were measured by DTPA extraction and their concentration were determined using atomic absorption spectrophotometer (AAS320CRT, Shanghai Analytical Instrument, Shanghai).

Statistical analysis

All the results are means of four replicates. Data were analyzed (SPSS statistical package

22.0) using one-way ANOVA and means separated using Duncan Multiple Range Test (DRMT) at $P \leq 0.05$. Correlation analysis was performed using Pearson correlation ($P < 0.01$).

RESULTS AND DISCUSSIONS

Wheat straw decomposition and soil respiration

There was an increase in the rate of soil respiration due to straw amendment compared to the NT (Fig. 1). The NT has its highest respired C of $111.63 \mu\text{g/g}$ soil per day on day 3 and then declined to $10.74 \mu\text{g/g}$ soil per day by the 61st day of incubation. Among the straw amended soils, RWI had the highest CO_2 -C respiration rate of $527 \mu\text{g/g}$ soil per day on the 4th day followed by GHI ($437 \mu\text{g/g}$ soil per day), and they end with 53.03 and $36.95 \mu\text{g/g}$ soil per day, respectively.

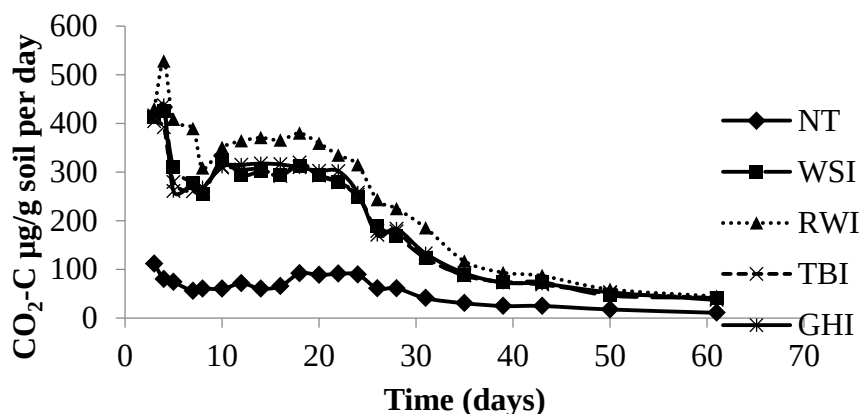
For straw placement options, at the beginning, respiration rate was faster in all straw mixed treatments than their corresponding straw layered treatments until 8th day, after which the pattern changed (Fig. 1). This could indicate that the effect of increase in straw-soil contact on respiration was only vivid at the onset of decomposition.

Among straw mixed treatments, WSI, GHI and RWI have their highest respiration on

day 4 after incubation while that of TBI was on day 3 after incubation (Fig. 1). In straw layered treatments, RWL and GHL have their highest respiratory rate on day 4, TBL day 10 and WSL treatment day 12 after incubation, suggesting an early establishment of RW and GH inoculants even when the contact between soil and straw was reduced while establishment of TB inoculant appeared to be delayed.

Except in RW treated soils, there were no significant differences in amount of respired C in inoculated soil compared to the uninoculated soils (Fig. 2). This could mean that inoculation does not increase the rate of CO_2 emission over uninoculated soils. The difference in the volume of CO_2 released from RW is attributed to the higher application rate (530 kg/ha) recommended by the manufacturer; hence it is suggested that 53 kg/ha of microbial product is preferred. Also, there were no significant changes in the pattern of CO_2 evolution due to inoculation except in RW in straw layered treatment between day 20 and 30 (Fig. 1b). For uninoculated straw, WSI has highest respiration rate of $423.7 \mu\text{g/g}$ soil per day on day 4 while that of WSL was $330.5 \mu\text{g/g}$ soil per day on day 12. This observation shows that performances of native microbes increase with the increasing contact with the straw.

a)



b)

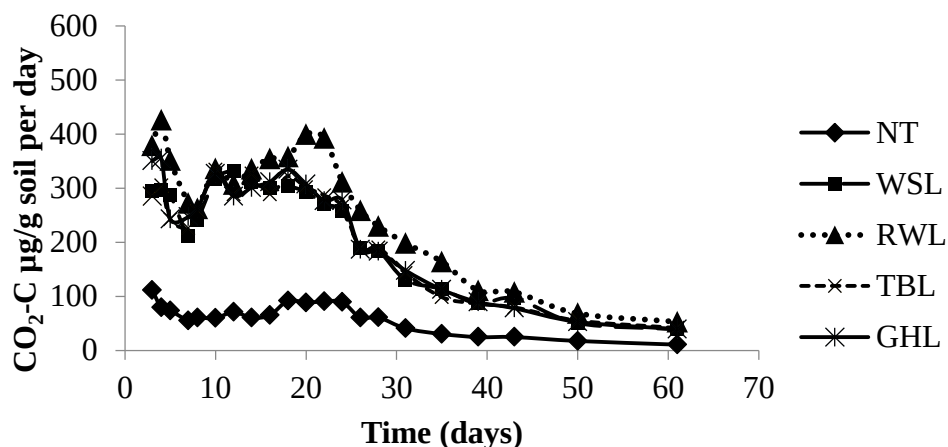


Figure 1:Rate of CO₂-C emission from soil treated with wheat straw and cellulose degrading microbial products.

Figure 2 and Table 3 show the cumulative CO₂ and daily average CO₂ of the amended soils, respectively. Straw amendment significantly ($P \leq 0.05$) increased cumulative CO₂ (Fig. 2) and average daily CO₂ (Table 3) over NT, suggesting an improvement in soil quality when straw is returned to the field. Inoculation with GH and TB did not significantly increase cumulative CO₂ and average daily CO₂ released compared to the uninoculated straw amended soils, but RW

did, in comparison to uninoculated straw amended soils.

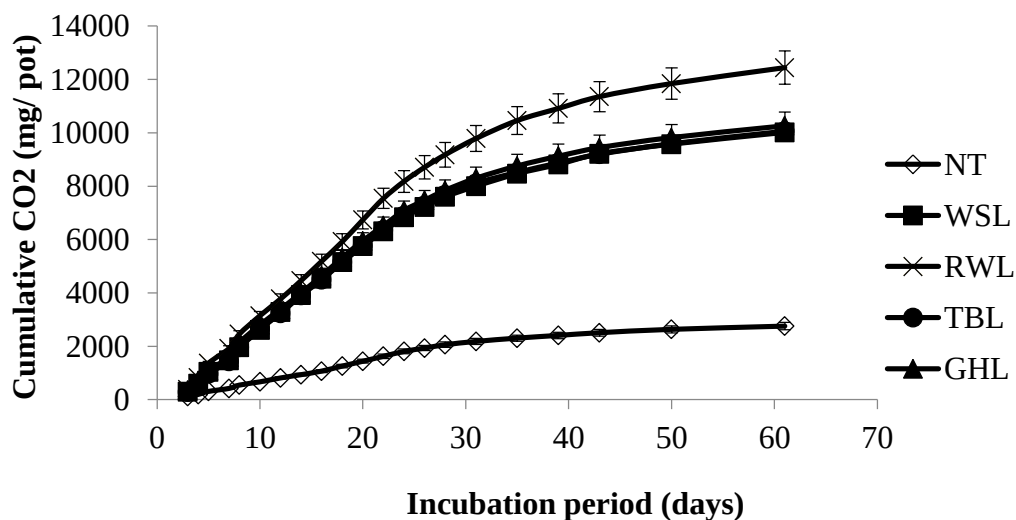
CO₂ evolution can be used as a measure of soil microbial activities and proxy for residue decomposition. The effect of inoculation on CO₂ emission rate was only vivid at the onset of the incubation period. Li et al. (2012) reported that the survival and performance of straw degrading inoculants is only significant at the early stage of decomposition. This conclusion is supported by Guo et al. (2008)

and Zhao et al. (2014), who reported increase in respiration rate of inoculated straw only at the early stage of decomposition compared to uninoculated straw treatments.

The results show that the inoculation and straw placement method had effects on the dynamics of wheat straw mineralization. The decomposition rate of uninoculated straw treatment was at par with the soil inoculated with TB and GH. However, higher application rate of RW increased both the evolution rate and cumulative CO₂ production for the two placement options. Generally, the performances of the inoculants might have been influenced by some factors such as the suitability of the strains in the

products for the intended use, their abundance in term of application rate or their ability to overcome the barrier usually created by the native soil microorganisms. Heijnen et al. (1988) and van Veen (1997) showed that some biotic factors (such as predation and competition) and abiotic factors (including clay minerals, water tension, pH and temperature) could affect population and activities of introduced inoculants in the soil. Also, it is possible that the increased decomposition by inoculation does not necessarily increase CO₂ released; rather the released carbon are likely found as increased DOC (Fig. 3) in the inoculated soil as shown in this experiment.

a)



b)

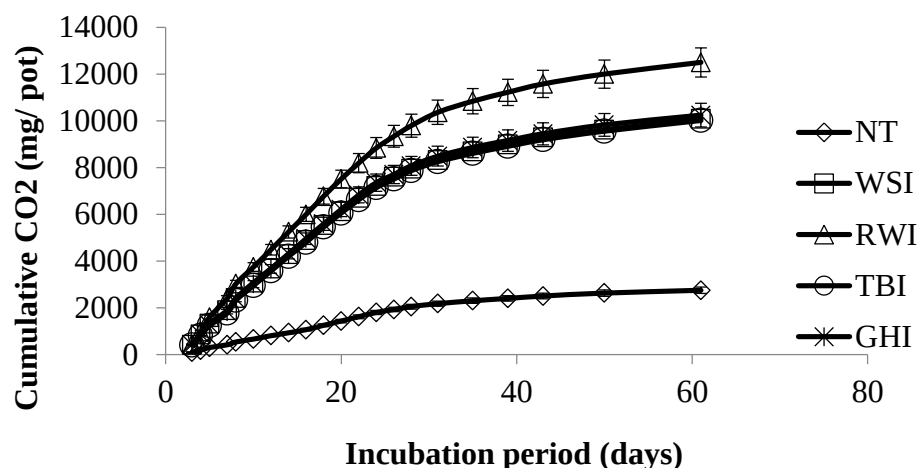


Figure 2: Cumulative respired C ($\text{CO}_2\text{-C}$) of wheat straw amended soils as influenced by straw placement method and exogenous microbial inoculants a) Soil-straw layered system and b) soil-straw mixed system.

Strong and rapid changes in the microbial community structure can be expected for the initial days of decomposition (Bending et al. 2002). The result of respiration curves in the current research show clear differences for the declining microbial activity after the initial peaks. In soil-straw layered treatments, the several peaks following each decline noticed on day 4 to around 25 is possibly due to the exhaustion of a specific C source which causes the rapid decline of microbial activity until a new microbial community is established to proceed with the decomposition process. In the straw mixed treatments, the initial peak was followed by a second peak but wider than the first one before the gradual decline to the end of the incubation. This shows initial maximum mineralization dynamics and support the view of an optimized and more efficient microbial succession for plant derived C sources due to the increase in contact between soil and straw. This result was

supported by findings of Henriksen and Breland (2002) and Potthoff et al. (2005) who concluded that the colonization of straw by holocellulose degraders, mostly consisting of fungi, is supported by increasing soil contact.

Dissolved soil organic carbon (DOC)

Soil dissolved organic carbon (DOC) was measured to investigate the effect of the amendments on soil labile carbon. The result showed that there was significant difference ($P \leq 0.05$) among the treatments. Straw amendment increased DOC over the control up to 291%. All inoculated soils had significantly higher DOC compared to uninoculated soils. The average increase was 40% indicating the positive effect of inoculation. Placement method also had an effect; higher amounts of DOC were found in all mixed treatments, whether or not they had been inoculated except in GHI. Although the difference was only significant within the

same inoculant in GH (Fig 3), this suggests that increasing soil–straw contact could improve soil labile carbon.

Soil organic matter defines energy supply to microorganisms, substrate availability and quality, and biodiversity necessary to sustain many soil functions. Fran et al. (2011) reported that soil labile carbon pool fraction represents proportion of soil carbon available for immediate consumption by soil microorganism, and could affect their

activities. Both straw addition and inoculation significantly increased soil labile organic carbon over control. An increase of up to three folds demonstrates the potential of the residue to improve soil fertility within a short time. The result also agrees with the report of Ogunniyi et al. (2014) and Zhu et al. (2014) where increase in soil labile organic C was recorded in straw amended soils in the laboratory and field experiment, respectively.

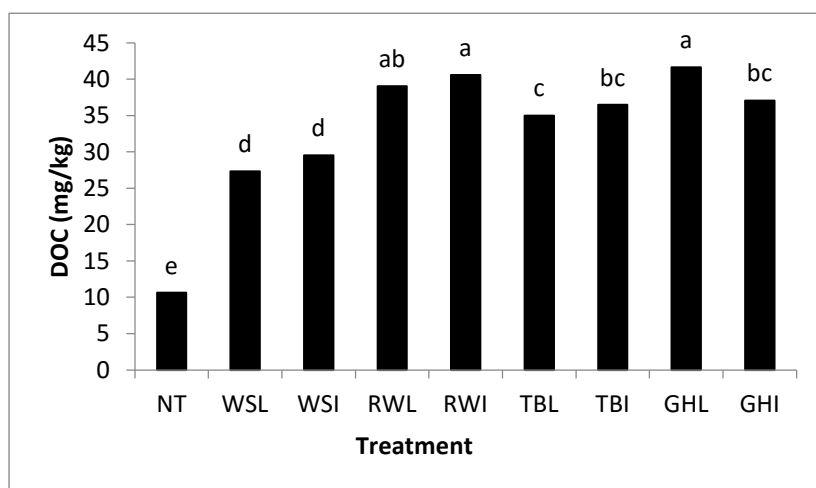


Figure 3: Soil dissolved (labile) organic carbon fraction as influenced by wheat straw amendment, straw degrading inoculants and wheat straw placement method ($P \leq 0.05$)

Influence of straw addition and inoculation on soil chemical properties

Soil available Phosphorus (P)

There was a significant difference in the means of the treatments in respect to available P (Table 3). Among the treatments, only RWI, RWL and WSI increased soil available P concentration over the control, but the increase was not significant for SWI, indicating that straw decomposition induced reduction in the initial concentration of the available P in the soil in the other treatments.

Straw placement option had no effect on the soil available P in this experiment. High P concentration in RW might associate with the increased rate of straw decomposition which might promote higher rate of P mineralization from the applied straw.

Total nitrogen, NO_3^- -N and NH_4^+ -N

Straw addition significantly increased soil total nitrogen over NT (Table 3). An increase of 49.5% - 54.8% was recorded in straw treated soil compared to no straw soil. The least value (7.94 g/kg) was found in WSI and

the largest value (8.87 g/ kg) in GHI treatment. No significant difference among the straw treated soils was observed. Generally, inoculation increased total N over pots where only straw was applied. Effect of the three inoculants used and placement options were similar in all the treatments.

The effect of amendments on nitrate nitrogen (NO_3^- -N) is shown in Table 3. There was significant difference among the treatments in respect to soil NO_3^- -N. Straw returning brought significant increase of up to 98.3% in soil NO_3^- -N over NT. Inoculation increased NO_3^- -N compared to uninoculated straw treatments. The performances of the three inoculants were relatively similar. Also, the effect of the placement options on the NO_3^- -N was similar in all the treatments as no significance difference was found between the two placement methods (Table 3).

The most important nutrients for many soils worldwide are N and P. Many soils are inherently low in P or have high P adsorption capacity while N is easily leached. This

problem can be exacerbated by the lack of nutrient replacement when removed by crop harvesting and erosion. Straw application has effect on soil P and N. The result shows increase in soil available P in soil only than all layered straw treated soils except in RW. The possible reason for the low P in most of the straw treated soils could mean higher rate of P immobilization into the microbial biomass or slower mineralization rate. The amount of P recovered from each treatment follows a pattern similar to total of CO_2 production; treatments with higher CO_2 evolution had higher soil available P.

The amount of total N observed in this experiment at the 61 day showed that N is not a limiting factor in this incubation work. The high NO_3^- -N in the straw amended soil can be attributed to the mineralization of the added fresh organic matter, which is known to have immediate effect on soil nitrate. The higher nitrate in the straw amended soils suggests availability of nitrogen for the subsequent crop.

Table 3: Soil available phosphorus, total N, NO_3^- -N and average CO_2 as influenced by the wheat straw addition and cellulose degrading microbial compounds

Treatment	Available P (mg/kg)	Total N (g/kg)	NO_3^- -N (mg/kg)	Net NO_3^- -N (mg/kg)	Average CO_2 respired (mg/day)
NT	11.6cd	4.0b	0.36 c	-	45.18c
WSI	13.7bc	8.3a	17.63 b	17.27	165.29b
WSL	10.0b	7.9a	18.11 ab	17.75	164.20b
RWI	15.3ab	8.7a	18.84 ab	18.48	204.94a
RWL	16.1a	8.9a	18.48 ab	18.12	203.96a
TBI	11.4cd	8.7a	18.28 ab	17.92	164.20b
TBL	9.8d	8.0a	18.61 ab	18.25	164.91b
GHI	11.6cd	8.6a	19.29 a	18.93	167.95b

GHL	10.6d	8.9a	18.04 ab	17.68	168.27b
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Different letters within a column indicate significant different ($p \leq 0.05$; $n = 4$)

Available Soil micronutrients (Fe, Cu, Zn and Mn)

The effect of straw amendment, placement method and inoculation on soil micronutrients is presented in Table 4. All the micronutrients determined in this project except Cu were significant at $P \leq 0.05$. Amount of iron (Fe) extracted from the control (NT) soil was significantly higher than all other treatments. This indicates that neither straw nor inoculation increase concentration of Fe in the soil. Among the straw treated soils, soil-straw layered had higher available Fe than corresponding soil-straw mixed treatments.

The lowest Zn concentration (0.42 mg/kg soil) was found in the control (NT) soil, this showed that straw application increased available Zn in the soil. GHL had the highest value (0.65 mg/kg soil) and was significantly different from NT, WSI, WSL and TBL. Among straw amended soils, uninoculated soils had the lowest Zn values. Thus, we could infer that inoculation of wheat straw amended soil could increase available zinc concentration in the soil. This could be of added advantage in soils where Zn deficiency in grains is typical. For Cu, NT has highest value of 0.56 mg/kg soil, but was not significantly different from other treatments.

This observation is possibly associated with Cu consumption by soil microbes during straw decomposition.

The most abundant of the four micronutrients determined was Mn. Straw amendment increased concentration of Mn compared to the NT, which was significantly lower than all the treatment. RWI had the highest value and was significantly higher than all other treatments while the NT has the least value (Table 4). Inoculation increased Mn concentration compared to the controls. All straw incorporated soils have slightly higher Mn concentration than their corresponding straw-soil layered treatments (Table 4) except for GH.

Concentrations of both Zn and Mn increased in comparison to the control while Cu and Fe decreased. The increased concentration of Zn and Mn is likely associated with increased mineralization rate. The inoculated treatments had higher Zn and Mn

concentrations compared to uninoculated soils suggesting the possibility that more of the nutrients were released as the straw decomposed under the influence of the inoculants. The decrease in the initial concentration of the Cu and Fe could mean higher consumption rate, since both of them play important role in the microbial respiration, and much of the needed Fe must have been derived from the soil. Other possible reason might be chelation of Fe and Cu by organic compounds formed during

straw decomposition. Tahir (1984) examined the effects of straw decomposition on availability of these four micronutrients and reported that no general trends could be found as the concentration of the micronutrients in soil varies with plant growth stages, type of amendment and soil

type. Unlike Tahir (1984) report, definite pattern were found for the four micronutrients after incubation. The differences between this study and that of Tahir are possibly due to the inoculation and crop uptake.

Table 4: Effect of straw amendment, straw inoculation and straw placement method on DTPA-extractable soil micronutrients

Treatment	Cu (mg/kg)	Zn	Fe	Mn
NT	0.56ns	0.42d	3.4a	6.4d
WSL	0.54ns	0.45cd	2.9b	11.4c
WSI	0.54ns	0.46bcd	2.4d	12.0bc
RWL	0.55ns	0.60abc	2.9b	12.2bc
RWI	0.53ns	0.61ab	2.7c	13.7a
TBL	0.52ns	0.47bcd	3.0b	12.4b
TBI	0.51ns	0.54abcd	2.6cd	12.8b
GHL	0.54ns	0.65a	3.1b	12.6b
GHI	0.49ns	0.57abcd	2.5cd	12.7b

Different letters within a column indicate significant different ($p \leq 0.05$; $n = 4$), ns = non significant

Relationship between respiration and measured soil properties

A Pearson correlation analysis of the total soil respiration and soil biological and chemical properties shows significant correlation except for Cu (Table 5). This suggests a strong, positive and significant relationship between soil respiration and soil TOC, total N, MBC, DOC, Mn and Zn ($p \leq 0.01$) and phosphorus ($p \leq 0.05$). This indicates that the addition of straw to soil enhanced these soil properties.

Negative correlation was found between soil respiration and available soil Fe and Cu. The relationship was significant ($P \leq 0.01$) for Fe while that of Cu is not significant (Table 5), suggesting that amending soil with wheat straw could result in reduced concentration of Fe and Cu. The correlation between total CO₂ and soil micronutrients follow the same pattern as shown in the concentration of the micronutrients extractable from the test soil after incubation (Table 4).

Table 5: Correlation between total soil respiration and measured soil biological and chemical properties

Variables	r value
CO ₂	--
TOC	0.74**
Total N	0.87**
Available P	0.45*
Cu	-0.19ns
Zn	0.46**
Fe	-0.57**
Mn	0.92**
DOC	0.89**
MBC	0.58**

Note: Correlation marked with double asterisk (**) means significant at $p < 0.01$, single asterisk (*) means significant correlation at $p < 0.05$, while ns means non-significant (n=36).

Residue decomposition rate could be measured by some microbial parameters such as respiration. Very high positive and significant correlation was found between CO₂ emitted and soil DOC, TOC, total N and Mn. This could mean that the concentrations of these elements in soil are strongly affected by freshly applied wheat straw. The correlation value between DOC and soil respiration was higher than that of MBC suggesting stronger influence of wheat straw decomposition on accumulation of DOC more than microbial carbon; thus DOC could be a better indicator of straw decomposition rate rather than MBC. The very strong relationship indicates the potential of decomposed wheat straw to improve soil labile carbon pool.

Positive correlation between soil respiration and Mn and Zn could implies increase in their concentration in soil as a result of straw decomposition; while negative relationship

between respiration and Fe and Cu predicts increase un-availability of the two micronutrients under straw amendment.

CONCLUSIONS

This study has shown that straw addition to soil and inoculation of straw does stimulate additional activity within the microbial community and that this might increase the rate of straw decomposition leading to an increase in some soil biological and chemical properties. One inoculant, RW, which application rate was tenfold higher than the rest, significantly increased cumulative CO₂

production in comparison to an uninoculated control. The other two inoculants, TB and GH, were comparable to the uninoculated control. This suggests that commercial inoculants have varying efficacy especially when application rate is different. Also, this work shows that exogenous inoculants can increase decomposition of wheat straw returned to soil without significant increase in CO₂ emission. The effect of increased soil-straw contact was only significant at the early stage of decomposition. Addition of straw has varying effect on soil micronutrient; it could increase Zn and Mn while reducing Fe and Cu in soil. This must be taken into consideration while planning amendments of arable soil with straw.

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