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Effect of farmyard manure, mineral fertilizers and mung bean residues on some microbiological properties of eroded soil in district Swat

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Abstract

The present study was conducted to evaluate the efficacy of organic and inorganic fertilizers and mung bean residues on improving microbiological properties of eroded lands of District Swat, North West Frontier Province (NWFP) Pakistan under wheat-mung bean-wheat cropping system during 2006 to 2008. The experiment was laid out in RCBD split-plot arrangement. Mung bean was grown and a basal dose of 25-60 kg N-P_2O_5 ha^{-1} was applied. After mung bean harvest, three residues management practices, i.e., R+ (mung bean residues incorporated into soil), R- (mung bean residues removed) and F (fallow) were performed in the main-plots. Sub-plot factor consisted of six fertilizer treatments for wheat crop i.e., T1 (control), T2 (120 kg N ha^{-1}), T3 (120-90-0 kg N-P_2O_5-K_2O ha^{-1}), T4 (120-90-60 kg N-P_2O_5-K_2O ha^{-1}), T5 (90-90-60 kg N-P_2O_5-K_2O + 10 t FYM ha^{-1}) and T6 (60-90-60 kg N-P_2O_5-K_2O + 20 t FYM ha^{-1}). The results showed that microbial activity, microbial biomass-C and-N, mineralizable C and N were highest with T6 as well as with the incorporation of mung bean residues (R+). Compared with control, T6 increased microbial biomass C, N, mineralizable C and N by 33.8, 164.1, 35.5 and 110.6% at surface and 38.4, 237.5, 38.7 and 124.1% at sub-surface soil, respectively, while R+ compared with fallow increased these properties by 33.7, 47.4, 21.4 and 32.2% at surface and 36.8, 51, 21.9 and 35.4% at sub-surface soil, respectively. Inclusion of mung bean with its residues incorporated and application of 20 t FYM ha^{-1} and reducing inorganic N fertilizer to 60 kg N ha^{-1} for wheat is recommended for improving microbiological properties of slightly eroded lands.

Keywords: Microbiological properties, eroded soil, crop productivity, residues management

Introduction

District Swat is mainly a mountainous area and farming is the major source of income for the local population (Soil Survey of Pakistan, 1976). Due to subsistence farming, cultivation on sloping land is a common practice, which has resulted in high runoff and soil losses leading to permanent degradation of soil fertility and crop productivity, as the top fertile soil layer is lost during the process, which influences all soil physical, chemical and biological properties (Lal, 1988; Pimentel *et al*., 1995).

Farmers have several options for correcting or compensating soil erosion and restoring productivity of eroded soils. One method for restoring eroded soil is to incorporate organic matter from any available sources, which protects soil against erosion. Recently the use of organic materials as fertilizers for crop production has received attention for sustainable crop productivity (Tejada *et al.*, 2009). Another strategy for managing soil erosion is the incorporation or use of plant residues. The application of plant residues have a positive effect on soil physical, chemical and biological properties, which contribute to its restoration (Tejada *et al.*, 2009) and has the potential to reverse the adverse effects of accelerated erosion on soil fertility (Kaihura *et al.*, 1999). The soil microbial community is an important component of soil (Tate, 2000). Biological properties of soils may be useful indicators of soil condition (Tejada *et al.*, 2008) as these properties respond more rapidly to soil degradation than do soil physical and chemical properties (Goyal *et al.*, 1999; Garcia *et al.*, 2000). Soil microbiological properties have the potential to be early and sensitive indicators of soil stress or productivity changes, and there is considerable evidence that they can be used to evaluate the influence of management and land use on soils (Saggar *et al.*, 2001). Microbial activity, microbial biomass C (MBC), microbial biomass N (MBN), mineralizable C and N are major soil microbiological properties and have frequently been used as indices of soil development or degradation (Izquierdo *et al.*, 2005; Bastida *et al.*, 2006; Marinari *et al.*, 2006; Tejada *et al.*, 2006; Crecchio *et al.*, 2007; Bastida *et al.*, 2008; Tejada *et al.*, 2008). Soil microbial respiration, measured through carbon dioxide production is a direct indicator of microbial activity, and indirectly reflects the availability of organic material (Tejada *et al.*, 2006; Tejada and Gonzalez, 2006). Increase in soil microbial biomass affects positively microbial and enzymatic activities (Tejada *et al.*, 2008).

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The objectives of the experiment were to evaluate the efficacy of organic and inorganic fertilizers and management practices of mung bean residues under wheat-mung bean-wheat cropping pattern for improving soil microbiological properties of slightly eroded land of Guljaba, District Swat.

Materials and Methods

Soil analysis before the experiment

Before the experiment triplicate soil samples were taken both from 0-20 cm and 20-45 cm soil depths from each site and analyzed at the laboratory of Soil and Environmental Sciences, NWFP Agricultural University, Peshawar. The details of the laboratory analysis are given in Table 1. It is evident from Table 1 that organic matter and most plant nutrients in the soils were either deficient or marginal as the soils were eroded.

Table 1: Soil analysis of experimental site before the experiment

Soil depth (cm)	0-20	20-45
$pH_{(1:5)}$	7.38	7.27
$EC_{(1:5)}$ (dS m^{-1})	0.85	0.89
Lime (g kg^{-1})	68.30	60.00
O.M (g kg^{-1})	11.93	11.77
ABDTPA Extractable P (mg kg^{-1} soil)	1.39	1.32
ABDTPA Extractable K (mg kg^{-1} soil)	60.60	61.17

Composition of farmyard manure and mung bean residues

Table 2 gives the details of the basic composition of FYM and mung bean residues used in the experiment. Dry weight of mung bean residues and FYM was 31.3 and 40.6%, total organic C was 180 and 163.8 g kg^{-1} dry matter, total N was 32.8 and 12.9 g kg^{-1} dry matter, while C:N ratio was 5.51 and 12.7, respectively.

Table 2. Basic composition of FYM and mung bean residues used in the experiment

Property of amendment	Mung bean residues	FYM
Dry weight (%)	31.30	40.6
Total organic C (g kg^{-1} DM)	180.70	163.8
Total N (g kg^{-1} DM)	32.80	12.9
C/N ratio	5.51	12.7

Field experiment

Field experiment was started in July 2006 on mung bean and wheat crops. The experimental design was two factors RCBD split-plot. Main-plot factor was residue management practices, which included three residue management practices, i.e., F (fallow), R- (Mung bean residues removed) and R+ (Mung bean residues incorporated). Sub-plot factor consisted of six fertilizers treatments, i.e., T1 (Control), T2 (120 kg N ha^{-1}), T3 (120-90 kg N-P_2O_5 ha^{-1}), T4 (120-90-60 kg N-P_2O_5-K_2O ha^{-1}), T5 (90-90-60 kg N-P_2O_5-K_2O ha^{-1} + 10 t FYM ha^{-1}), and T6 (60-90-60 kg N-P_2O_5-K_2O ha^{-1} + 20 t FYM ha^{-1}). During Kharif 2006, mung bean variety Swat-97 was first sown in two of the three main-plots, while the third main-plot was left fallow. Immediately after harvesting, aboveground residues of mung bean crop were either completely removed (R-) or incorporated with the help of cultivator (R+) into respective plots according to the plan.

In November 2006 during Rabi 2007, wheat variety Tatara was sown in all the plots. Sub-plot size was 5 m x 4 m. All the fertilizer treatments were applied to their respective plots at the time of sowing of wheat crop and were incorporated into the soil. In case of NPK treatments, half N plus all P, and K were applied at sowing and the remaining half N after one month of sowing. Farmyard manure was applied at the rate of 10 t ha^{-1} in T5 and 20 t ha^{-1} in T6 plots about one month before sowing of wheat crop during the two winter seasons. Wheat crop was harvested in June each year and threshed after sun drying in the field. The experiment was repeated for the next year for two seasons, i.e., Kharif 2007 and Rabi 2008.

Laboratory procedures

Soil samples were collected from each treatment plot at two depths i.e., 0-20 cm and 20-45 cm in June 2008 with a gauge auger (30 mm diameter) at the harvest of wheat crop and brought to the laboratory of the Department of Soil & Environmental Sciences, NWFP Agricultural University, Peshawar. Soil samples were air dried at room temperature, sieved (2 mm) and stored at 4°C. Microbial biomass carbon (C) and nitrogen (N) were determined by the method described by Jenkinson and Powlson (1976). Twenty gram soil sample was fumigated with chloroform to kill all microbes and then inoculated with 1g fresh un-fumigated soil. This was then incubated for 2, 5, 10 and 15 days in the presence of NaOH in a vial suspended inside the flask to trap the evolved CO_2. Twenty g of the same soil sample was taken in another beaker without chloroform fumigation and incubated for the same time in the presence of NaOH to trap the CO_2 evolved. Microbial biomass C was determined by using the equation; Biomass C = (Fc-Ufc)/Kc Where Fc

= CO_2 produced from fumigated soil, Ufc = CO_2 produced from un-fumigated soil, Kc = 0.45 (Jenkinson and Ladd, 1981). The amount of soil microbial biomass N was calculated by using the following equation; Biomass N = (Fn-Ufn)/Kn Where Fn = NH_4-N mineralized during 10 days from fumigated soil, Ufn = NH_4-N mineralized during 10 days from un-fumigated soil, Kn = 0.54 (Jenkinson, 1988). Mineralizable-C was estimated from the total amount of CO_2 produced from an un-fumigated soil sample during 10 days of incubation. The amount of mineralizable C was calculated on the basis that 44 g of CO_2 contains 12 g of C. Mineralizable-N was determined in same sample run for measuring mineralizable-C. The sample was analyzed for mineral-N before incubation (day 0) and after incubation (day 10). The amount of mineralizable-N was calculated as follows:

Mineralizable N = Mineral-N at day 10 - Mineral-N at day 0

Statistical analysis

The collected data on different soil properties were analyzed statistically using two Factors RCBD Split-plot with three replications using MS Excel and statistical package MStatC. Treatments were compared using LSD test of significance at 5% level of significance according to Gomez and Gomez (1976).

Results

Microbial activity (CO_2 evolution)

Effect of fertilizer treatments on cumulative CO_2 evolved during 2, 5, 10 and 15 days incubation was significant ($P<0.05$) at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth). Treatment T6 had the highest microbial activity followed by T5 (Figure 1).

Residue management practices had also significant ($P<0.05$) effect on cumulative CO_2 evolved during 2, 5, 10 and 15 days incubation at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth). R+ resulted in highest microbial activity followed by R-, while fallow plots had the lowest microbial activity (Figure 2).

Microbial biomass carbon

Effect of fertilizer treatments on microbial biomass carbon was significant ($P<0.05$) at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth). Treatment T6 had the highest microbial biomass carbon followed by T5 (Table 3). As compared to control, the respective increases in microbial biomass C at surface and sub-surface soils by T5 were 25.6 and 31.2% and by T6 were 33.8 and 38.4%.

Residue management practices had significant ($P<0.05$) effect on microbial biomass carbon at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth). R+ resulted in highest microbial biomass carbon followed by R-, while fallow plots had the lowest microbial biomass carbon (Table 4). As compared to fallow, the respective increases in microbial biomass C at surface and sub-surface soils by R- were 15.9 and 18.9% and by R+ were 33.7 and 36.8%.

Microbial biomass nitrogen

Effect of fertilizer treatments on microbial biomass nitrogen was significant ($P<0.05$) at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth). Treatment T6 had the highest microbial biomass nitrogen followed by T5 (Table 3). As compared to control, the respective increases in microbial biomass N at surface and

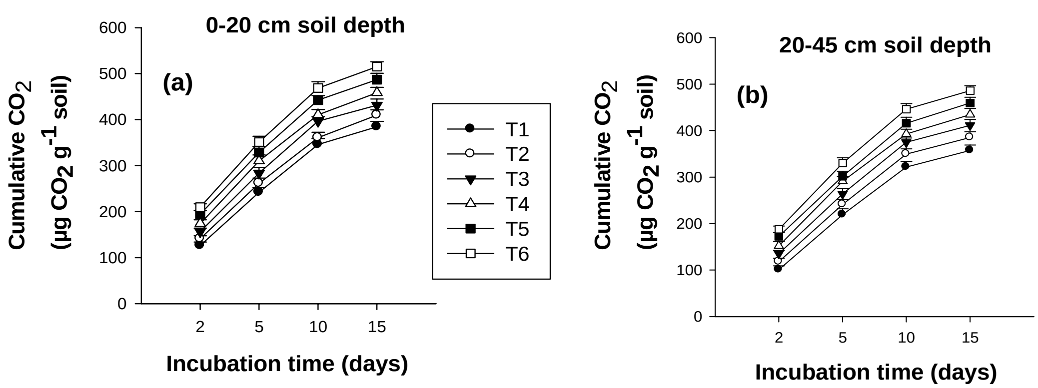

Figure 1. Effect of fertilizer treatments on cumulative CO_2 (mg CO_2 kg^{-1} soil) evolved during 2, 5, 10 and 15 days incubation (a) at surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) (LSD ($P<0.05$))

sub-surface soils by T5 were 130.8 and 188.6% and by T6 were 164.1 and 237.5%, respectively.

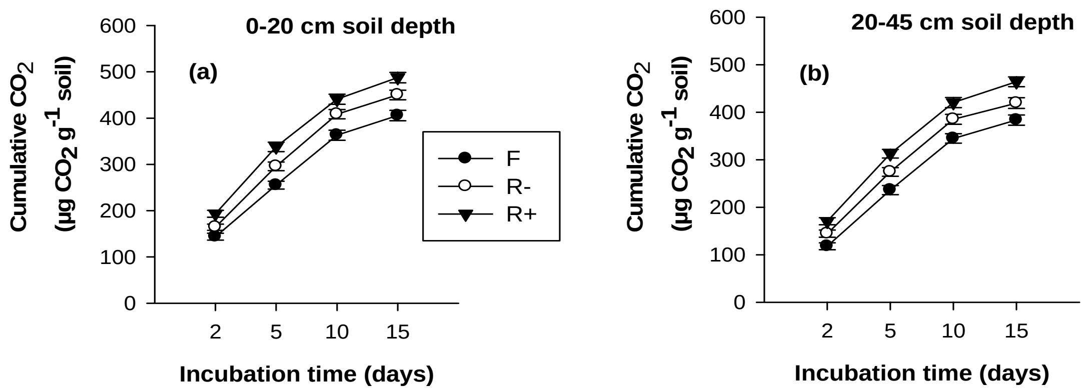

Figure 2. Effect of residues management practices on cumulative CO_2 (mg CO_2 kg^{-1} soil) evolved during 2, 5, 10 and 15 days incubation at (a) surface (0-20 cm soil depth) and (b) sub-surface (20-45 cm soil depth) (LSD (P<0.05))

Residue management practices had significant (P<0.05) effect on microbial biomass nitrogen at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth). R+ resulted in highest microbial biomass nitrogen followed by R-, while fallow plots had the lowest microbial biomass nitrogen (Table 4). As compared to fallow, the respective increases in microbial biomass N at surface and sub-surface soils by R- were 22.5 and 26.8% and by R+ were 47.4 and 51%, respectively.

Mineralizable C

Effect of fertilizer treatments on mineralizable C was significant (P<0.05) at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth). Treatment T6 had the highest mineralizable C followed by T5 (Table 3). As compared to control, the respective increases in mineralizable C at surface and sub-surface soils by T5 were 27.9 and 29.3% and by T6 were 35.5 and 38.7%.

Residue management practices had significant (P<0.05) effect on mineralizable C at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth). R+ resulted in highest mineralizable C followed by R-, while fallow plots had the lowest mineralizable C (Table 4). As compared to fallow, the respective increases in mineralizable C at surface and sub-surface soils by R- were 12.5 and 11.7% and by R+ were 21.4 and 21.9%.

Mineralizable N

Effect of fertilizer treatments on mineralizable N was significant (P<0.05) at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth). Treatment T6 had the highest mineralizable N followed by T5 (Table 3). As compared to control, the respective increases in mineralizable N at surface and sub-surface soils by T5 were 88.2 and 96.5% and by T6 were 110.6 and 124.1%.

Residue management practices had significant (P<0.05) effect on mineralizable N at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth). R+ resulted in highest mineralizable N followed by R-, while fallow plots had the lowest mineralizable N (Table 4). As compared to fallow, the respective increases in mineralizable N at surface and sub-surface soils by R- were 16.4 and 19.8% and by R+ were 32.2 and 35.4%.

Discussion

Effect of fertilizer treatments on soil biological properties

Effect of organic and inorganic fertilizer treatments on microbial activity, microbial biomass C and N and mineralizable C and N was significant. Compared to other treatment T6 had better microbial properties followed by T5, which included FYM additions.

Increase in microbial activity, biomass C and N and higher mineralization of C and N can be attributed to a positive effect caused by incorporation of FYM in the soil, which improves moisture conservation in the soil stimulating microbial activity of the soil as well as addition of exogenous microorganisms. Continuous application of FYM with inorganic fertilizers increased the mineralizable-C and -N and mineral -N significantly due to the reason that continuous application of FYM increased the organic matter and more root biomass production due to enhanced crop growth. Results revealed that application of mineral fertilizers also increased microbial biomass N, and mineralizable N in both the surface and sub-surface soils. The maximum microbial biomass C and N and mineralizable C and N were recorded in combined application of farmyard manure and mineral fertilizers. Combined application of organic and inorganic fertilizers increased soil organic matter content in the soil that provide carbon source and other nutrients for microbes, which enhance microbial activity and result in improved microbial properties.

Table 3. Effect of fertilizer treatments on microbial biomass C and N and mineralizable C and N at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth)

Treatment	MBC[a]	MBN	C_{min}	N_{min}
			(mg kg^{-1} soil)	
Soil depth = 0-20 cm				
T1	358.8 f[b]	11.7 f	094.3 f	16.1 f
T2	384.5 e	15.4 e	098.3 e	19.3 e
T3	400.3 d	19.2 d	108.1 d	22.8 d
T4	426.5 c	23.9 c	111.9 c	26.5 c
T5	450.8 b	27.0 b	120.6 b	30.3 b
T6	480.2 a	30.9 a	127.8 a	33.9 a
$LSD_{(0.05)}$	007.51	00.75	002.46	00.82
Soil depth = 20-45 cm				
T1	325.7 f	08.8 f	087.7 f	14.1 f
T2	349.2 e	13.5 e	095.3 e	17.4 e
T3	374.2 d	17.2 d	102.2 d	21.0 d
T4	394.9 c	21.2 c	107.0 c	24.8 c
T5	427.4 b	25.4 b	113.4 b	27.7 b
T6	450.7 a	29.7 a	121.6 a	31.6 a
$LSD_{(0.05)}$	007.98	00.68	002.99	00.75

[a] MBC = Microbial biomass C (mg kg^{-1} soil), MBN = Microbial biomass N (mg kg^{-1} soil), C_{min} = mineralizable C (mg C kg^{-1} soil), and N_{min} = mineralizable N (mg N kg^{-1} soil).

[b] Means followed by same letter(s) in a column are statistically non-significant at the P<0.05 level.

Similar results have been reported by many workers (Goyal *et al.*, 2006; Masto *et al.*, 2006; Manna *et al.*, 2007), who concluded that microbial activity, microbial biomass-C and-N increased significantly with balanced application of fertilizer and combined application of FYM and inorganic fertilizers. The readily metabolizable-C and -N in organic manures in addition to increasing root biomass and root exudates due to enhanced crop growth are the most influential factors contributing to the biomass increase. The labile fraction of organic matter is the most degradable and therefore the most susceptible to mineralization, acting as an immediate energy source for microorganisms (Tejada *et al.*, 2009).

Effect of residues management practices on soil biological properties

Incorporation of mung bean residues improved soil biological properties, while leaving the plots fallow led to degraded soil biological properties. The highest microbial activity, microbial biomass C and N and mineralizable C and N were found in plots where mung bean residues were incorporated into the soil. Incorporation of mung bean residues into the soil stimulates soil microbial growth and activity with subsequent mineralization of plant nutrients. Tejada *et al.* (2009) also found that plant residues had a positive effect on soil biological properties (biomass C and the enzymatic activities). This might also be attributed to more N_2 fixation and N released from organic matter decomposition and subsequently incorporated into microbial biomass. The nodulated roots and above ground residues, after the mung bean harvest, represent a valuable source of N and soil organic matter and their decomposition provides a meaningful contribution to soil N. These results are supported by many workers (Schaffers, 2000; Tejada *et al.*, 2006; Tejada and Gonzalez, 2006; Stark *et al.*, 2007; Tejada *et al.*, 2008).

Table 4. Effect of residues management practices on microbial biomass C and N and mineralizable C and N at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth)

Treatment	MBC[a]	MBN	C_{min}	N_{min}
	(mg kg^{-1} soil)			
Soil depth = 0-20 cm				
F	357.7 c[b]	17.3 c	099.0 c	21.4 c
R-	414.6 b	21.2 b	111.4 b	24.9 b
R+	478.2 a	25.5 a	120.2 a	28.3 a
$LSD_{(0.05)}$	006.70	00.68	003.13	00.95
Soil depth = 20-45 cm				
F	326.4 c	15.3 c	094.0 c	19.2 c
R-	388.1 b	19.4 b	105.0 b	23.0 b
R+	446.6 a	23.1 a	114.6 a	26.0 a
$LSD_{(0.05)}$	002.89	01.08	001.21	01.22

[a] MBC = Microbial biomass C (mg kg^{-1} soil), MBN = Microbial biomass N (mg kg^{-1} soil), C_{min} = mineralizable C (mg C kg^{-1} soil) and N_{min} = mineralizable N (mg N kg^{-1} soil).
[b] Means followed by same letter(s) in a column are statistically non-significant at the P<0.05 level.

Conclusions

Application of organic and inorganic fertilizers and residues management improved microbiological properties of slightly eroded soil Guljaba. Inclusion of mung bean with its residues incorporated and application of FYM combined with inorganic fertilizers (T6 = 60-90-60 kg N-P_2O_5-K_2O ha^{-1} + 20 t FYM ha^{-1}) to wheat crop gave the best results improving soil microbiological properties and hence is recommended for slightly eroded lands.

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